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JOURNAL

AIR POLLUTION CONTROL ASSOCIATION

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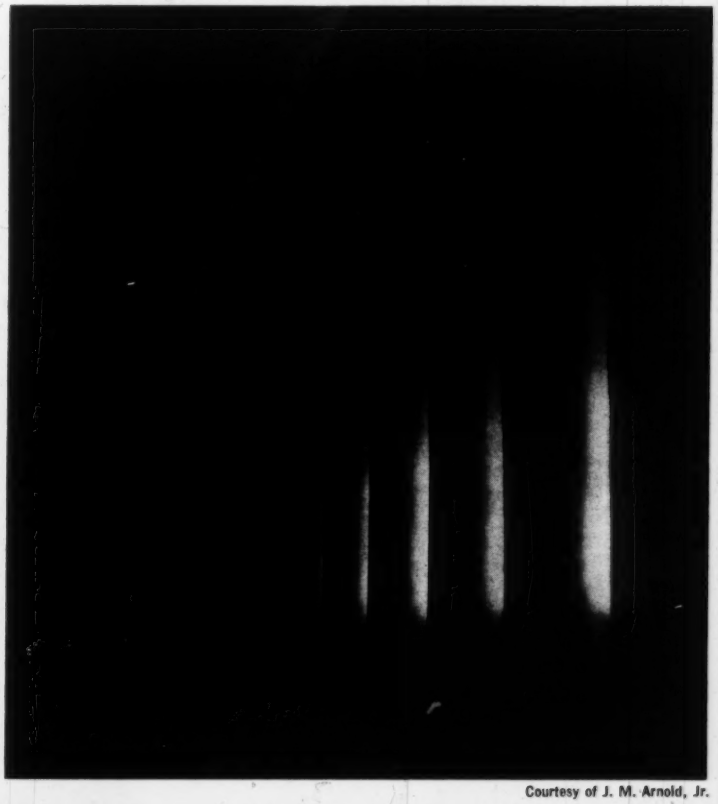

Courtesy of J. M. Arnold, Jr.

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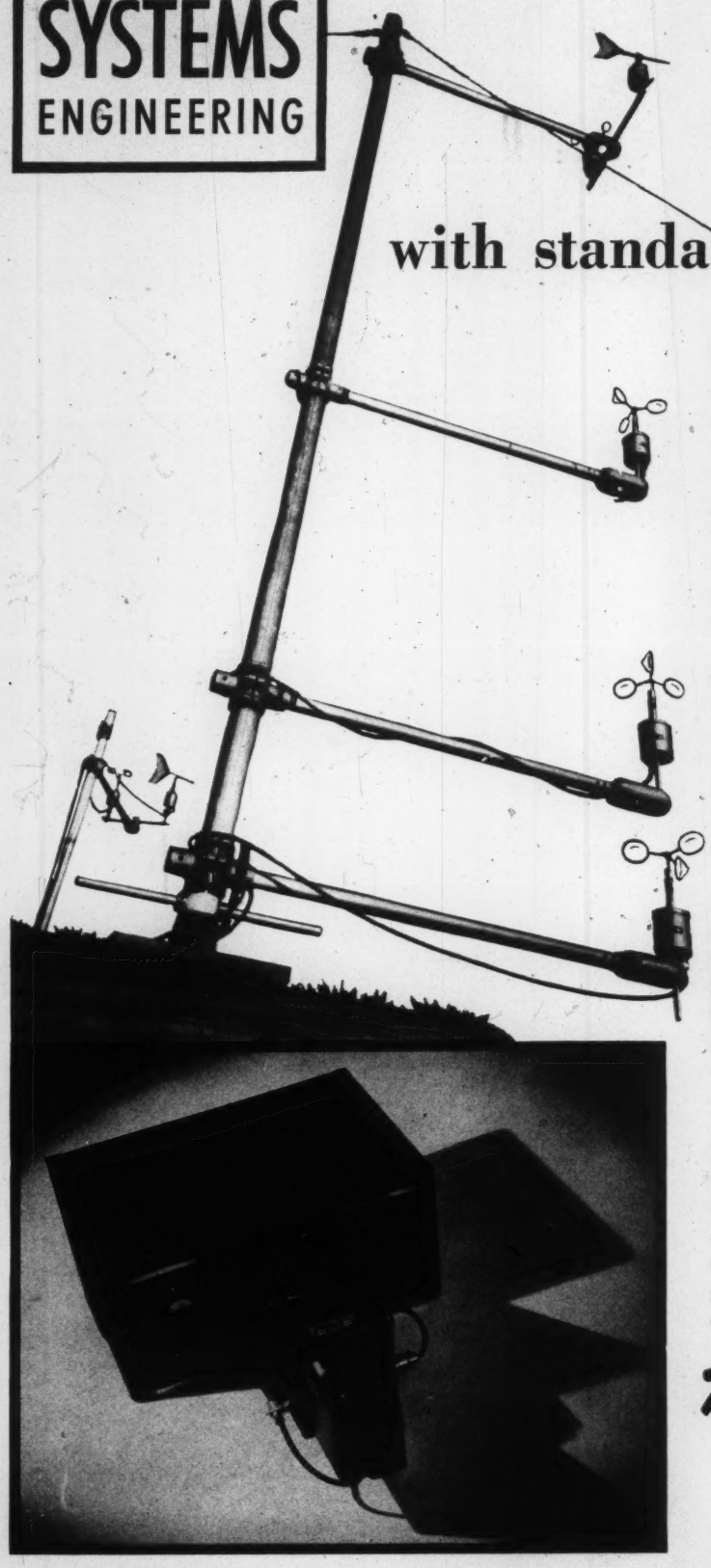

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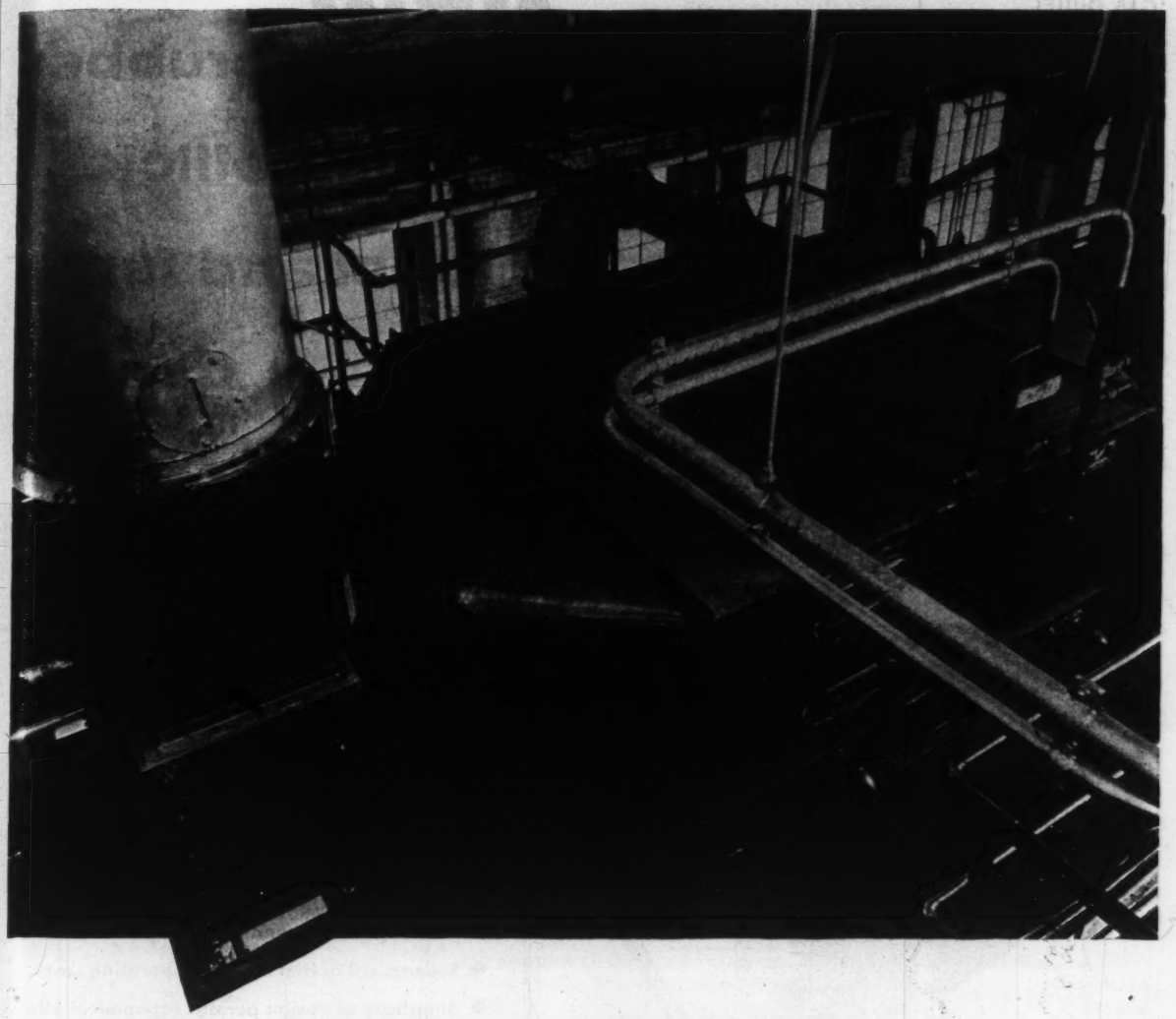

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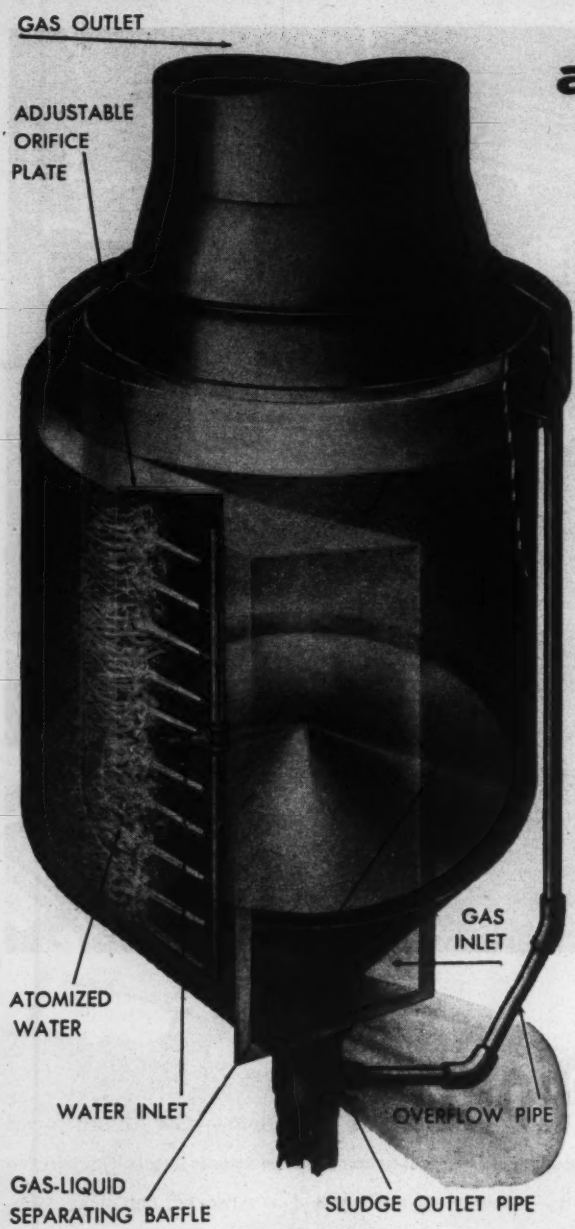

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JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION

A Monthly Journal
Devoted to
Air Purification

Editor: Arnold Arch
Associate Editor: Pat Truschel
Assistant Editor: Pat Martin

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The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

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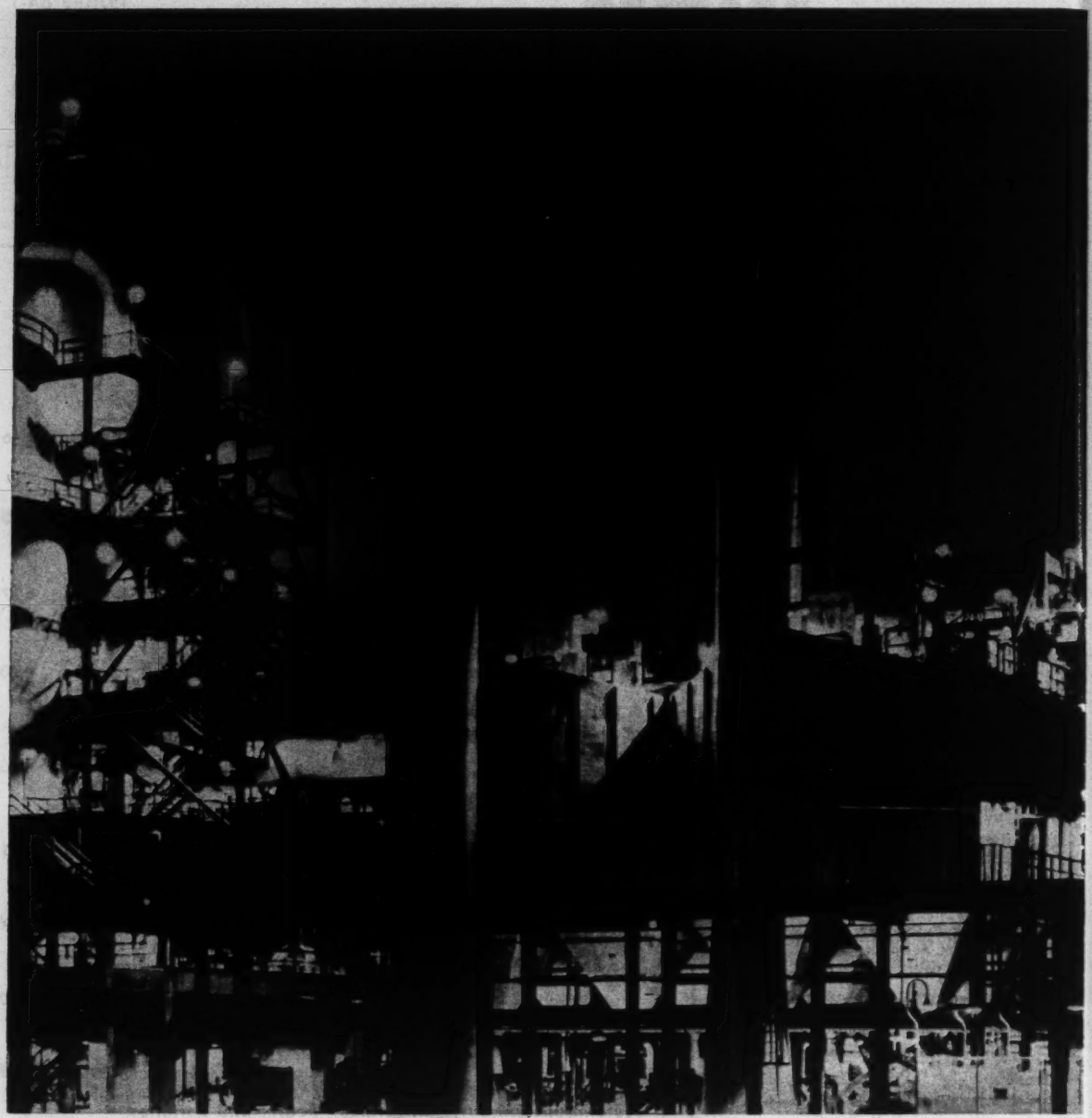

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LETTERS to the EDITOR

Congratulations

Gentlemen:

After attending the 17th meeting of the East Central Section of the Air Pollution Control Association in Detroit, I am moved to write to you to tell you how much we enjoyed this, and that we think this kind of meeting will bring great value to every urban community by clarifying the problems and pointing the way to economical solutions.

If at all possible we would like to attend your meetings whenever they will be held in or near Detroit.

Although this meeting was undoubtedly a success, we think future meetings should be better attended due to the good will and publicity already established.

We wish you even greater success.

B. P. SHILLER

Critique

Dear Sir:

The APCA TI-2 Chemical Committee report in the April, 1960, *APCA Journal* is not, in my opinion, representative of the best information and ideas available in the membership of the Air Pollution Control Association.

As a member of the Technical Council, I brought information and viewpoints along the following lines to the attention of the Chemical Committee in writing during early 1959.

The editorial tone of the report is negative and defensive, as I read it. The approach to the industry-air pollution control official relationship seems to be considerably out of date. A section by section critique of this report follows:

The Foreword is entitled, "The Chemical Industry's Air Pollution Problem." In this section there is no mention of any of the air pollution problems in the chemical industry. The entire foreword discusses the competitiveness of the chemical industry and it is difficult to know what inferences are to be drawn from this kind of a discussion. I am sure that this does not mean that the chemical industry, because of its competitiveness, does not want to carry its fair share of the burden of air pollution control costs. The writers apparently wish to make the point that since the chemical industry is so highly in-

(*Continued on p. 470*)

SECRETARY'S PAGE

APCA PROGRESSES

Membership Votes for Dues Increase

The Tellers Committee has counted the ballots for the vote deciding increase of membership dues. A total of 719 ballots were received, 517 of these were for approval of the By-Law change, and 169 disapproved the change; 33 ballots were invalid. It is significant that almost 40% of the membership voted, and that the two-thirds of all members voting, required for approval in accordance with the By-Laws, was exceeded by a complete majority. It is interesting to note that another large technical society recently had a by-law amendment voted upon by its membership with only 11% voting. Several actions of the Board will require that additional dollars, received from the dues increase, will be put to work immediately.

Board Authorizes Monthly Publication of the JOURNAL

At its recent meeting, on October 25, 1960, in Pittsburgh, the Board of Directors took several important actions. Most important of which was authorization to commence monthly publication of the JOURNAL, commencing January, 1961. This is, no doubt, the outstanding development taken by your association's Board since APCA was revitalized in 1951 and moved to the Mellon Institute. Some of the other important actions of the Board at this meeting are as follows:

1. Referred back to the Legal Committee, with instructions for clarification, a resolution concerning rules making procedures by control agencies. This is a policy matter proposed by the Legal Committee.

2. Returned to the Public Relations Committee for a condensation a policy statement of the public relations policies of APCA.

3. Moved for adoption as a change in By-Laws an amendment concerning powers of the Executive Committee.

4. Initiated a By-Law amendment concerning dissolution and disposal of funds in accordance with the recommendations of the Internal Revenue Department to fit requirements of APCA as a nonprofit association.

5. Accepted a report of Vice President V. G. MacKenzie summarizing past APCA Board policies.

6. Accepted final financial report of the 53rd annual meeting held in Cincinnati.

7. Accepted report of Dr. W. L. Faith's membership committee and membership drive. The names of this new membership committee are listed on another page in a special report on membership activities.

8. Discussed missions and objectives of the "Future of APCA" Committee, as reported by its Chairman "Liv" Ireland.

9. Authorized monthly publication of the JOURNAL, effective January, 1961, and authorized expenditures of APCA's reserve funds in the amount of $30,000 for the two year period beginning with fiscal May 1, 1961, if necessary, to continue publication for at least two years. It is hoped that this encroachment on reserve will not be necessary due to expanded membership, dues increase, and increased advertising revenue.

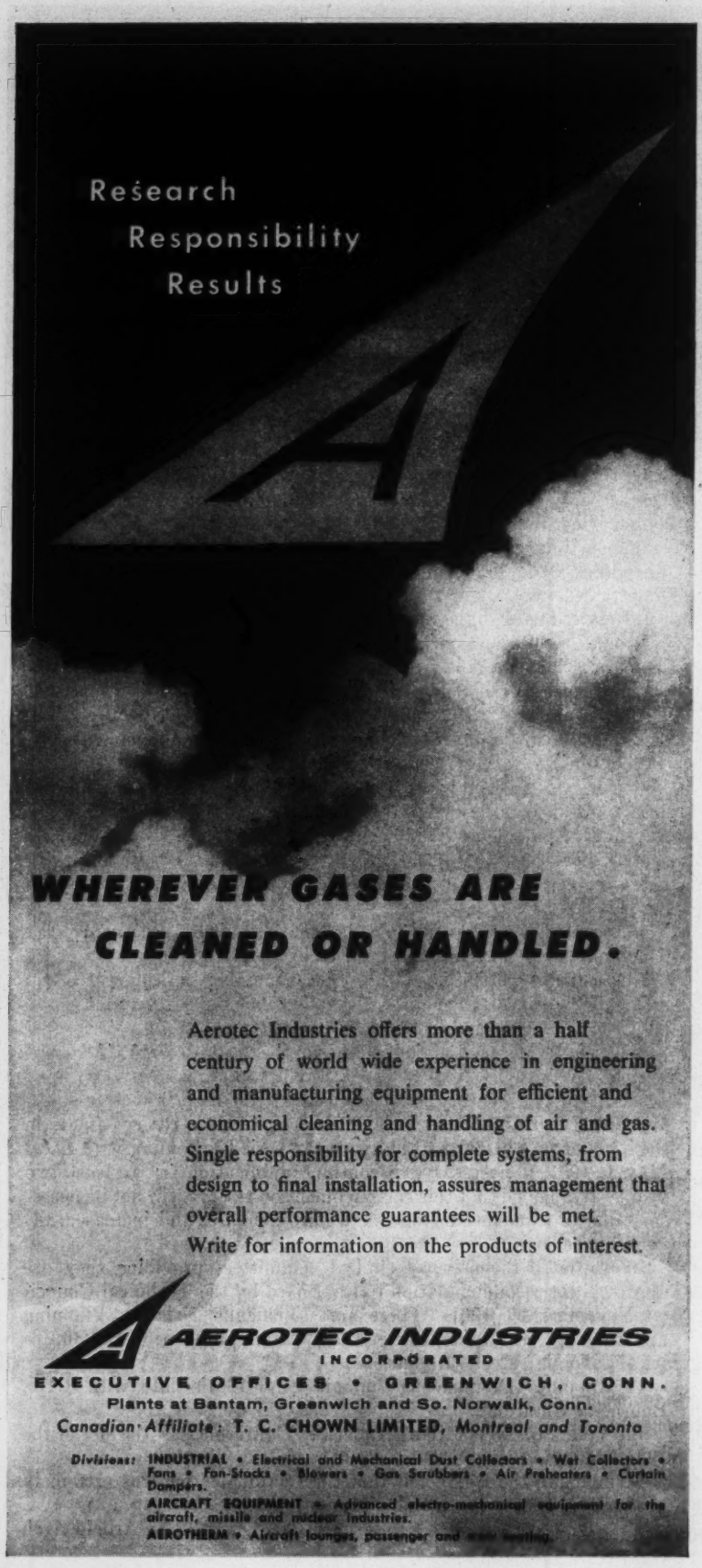
10. Initiated seven new technical committees providing they are approved for recommendation to the Board by the Technical Council on November 15, 1961. These are: Vehicular Exhaust, Planning and Zoning, Consultants, International Affairs, Education and Training, Economic Effects, Radiation.

11. Appointed Nominating Committee for 1961's slate, with R. W. Bourne as Chairman.

12. Voted to accept San Francisco, California, as the site of the 1966 annual meeting.

Members of the Board felt that the Board Meeting was extremely productive from every standpoint.

Arnold Arch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DR. FLORY RESIGNS POST; WILL STAY IN RESEARCH

Dr. Paul J. Flory has resigned as Executive Director of Research and as a Trustee of Mellon Institute, and will remain at the Institute to give full time to research in the field of polymer science.

Paul Mellon, Chairman of the Board of Trustees of the Institute, made the announcement following a meeting of the Board. Mr. Mellon said, "With much reluctance and regret, we have accepted Dr. Flory's resignation of his administrative post. We are happy that he will continue as a member of the Senior Staff.

"During the past four years, he has brought to Mellon Institute a group of notable young research scientists in basic chemistry and metal physics. In accepting Dr. Flory's withdrawal from his administrative post, the Trustees reaffirmed strongly the programs originated by this group and the policies governing basic research which have prevailed and been carried into effect during his administration."

Committee Appointed

While no successor to Dr. Flory has been named, Mr. Mellon said, the advice and guidance of its Research Directors will be depended upon to maintain the momentum of the broadened scientific plan of the Institute. For this purpose the Trustees have authorized the appointment of an executive committee composed of senior members of the research staff of the Institute.

Mr. Mellon also announced the election of a new trustee, Stoddard M. Stevens, of the law firm of Sullivan and Cromwell, New York City. Mr. Stevens received his A.B. degree from Cornell University in 1914, and his LL.B. from Columbia University in 1917. He joined Sullivan and Cromwell in 1917 and became a member of the firm in 1929.

Mr. Stevens is a director of Babcock and Wilcox Company and Bailey Meter Company. He is also a trustee of several institutions and foundations, and is a member of the American, New York State, and New York City bar associations.

In Memoriam . . .

It is with deep regret we announce the deaths of Irving M. Thomas of Los Angeles, California, on August 14, 1960; and Frank A. Sinning of Rocky River, Ohio, on August 5, 1960.

CONTINUOUS *Parts per Billion* RECORDER *for Air* CONTAMINANTS*

JOHN P. STRANGE, Manager, Applied Research and Engineering, **KENNETH E. BALL,** Research Physicist, **DONALD O. BARNES,** Assistant Physicist, Mine Safety Appliance Company, Pittsburgh, Pennsylvania

Beginning with the first awakening to problems of air contamination, particularly in industrial areas, there has been a recognized need for instruments to continuously monitor atmospheres for a variety of toxic or noxious compounds. Because constant exposure to even minute concentrations of many substances in common use or occurring as waste products in modern industry is injurious to health and property, such air monitoring instruments must have high sensitivity and specificity.

The usual approach to the development of a continuous analyzer has been to instrument a chemical analysis procedure which has proved satisfactory in the laboratory. Instruments developed on this basis have the advantages of a high degree of specificity and frequently achieve high sensitivity by concentrating the compound of interest from a large volume of air sample. This need to accumulate the detected contaminant to obtain a sufficient amount for reliable measurement imposes definite disadvantages. In some instances the instrument operates with a programmed cycle of collection, analyses, and read-out phases so that there is always a dead period when the instrument is not sampling and a delay before the results of the analysis are made known.

More truly continuous analyzers have been devised in which the air contaminant is accumulated by impingement on a chemically treated tape or into a liquid scrubbing solution. The reactant tape or liquid is then assayed for the contaminant or preselected reaction products by physical or physical-chemical techniques. Changes in light transmission or reflectance and fluorescence enhancement or inhibition are well-known methods of assaying the reaction on tapes. Potentiometric, conductimetric, polarographic, and coulometric techniques are most common for liquids.

As in the batch type analyzers, high sensitivity in the continuous recorders depends upon reacting the contaminant from a large volume air sample with a small amount of indicating reagent. Tape or liquid transport or exposure time must therefore belong with the attendant lag in recording of the information. Rapid concentration fluctuations are averaged and sudden buildup to toxic levels may not be indicated immediately.

Some strictly physical principle instruments have been devised which overcome the delays entailed with chemical techniques. Although some of these instruments such as special ultraviolet or infrared spectrophotometers have been successfully used to monitor the air for certain compounds, sensitivity is generally too low to adequately detect and measure concentrations in the parts per billion or low parts per million range.

To develop a continuous recorder capable of responding instantaneously to trace concentrations of air contaminants, we have used an unique combination of chemical and physical principles.

Detecting Contaminants by Ionization Phenomena

The detecting and measuring techniques used in the M.S.A. Billion-Aire to monitor atmospheres for trace contaminants has been described before.[1–3] It is therefore reviewed only briefly here.

Several properties of ionized gases lend themselves, in principle, to the detection of impurities in pure gases or simple gas mixtures. Among these are excitation and ionization potential, ion mobility and recombination rate. When a gas is ionized between two oppositely charged electrodes, a current is conducted depending primarily on the strength of the ionizing source, the applied voltage, and the composition and pressure of the gas. Because of the affinity of the oxygen molecule for electrons, the current between the electrodes, when air is ionized, is carried by positive ions and negative ions formed by the O_2-electron attachment. The magnitude of the current—if the ionizing source, the voltage across the electrodes, and the pressure are constant—is a function of the mobility and recombination rate of the ions.

With air in the chamber, most gaseous additives in concentrations of several thousand parts per million will cause only small changes in the ion current. However, very small concentrations of finely divided particulate matter produce a pronounced decrease in current. The action of the particles is to promote effective recombination through third body collisions and to decrease mobility through attachment. By converting a

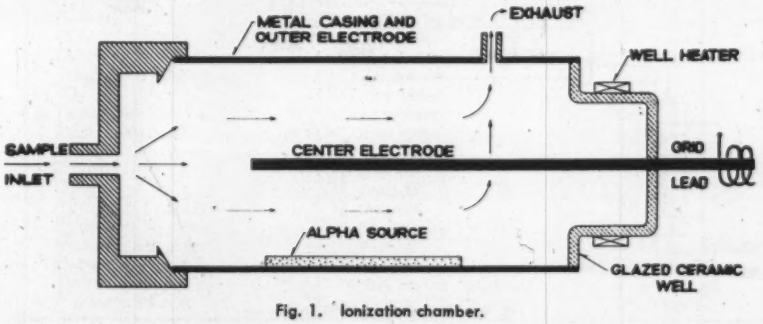

Fig. 1. Ionization chamber.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

gas to particulate matter by a suitable reaction and measuring the decrease in ion current due to the presence of the particles in an ion chamber, various toxic or noxious air contaminants can be detected in concentrations of a few parts per billion.

The Ion Chamber Detector

Figure 1 is a schematic drawing of the specially constructed ion chamber used in the sensitive air monitor. The chamber is cylindrical with the outer wall forming one of the electrodes. The center electrode is supported by a ceramic insulator which is heated electrically, keeping it dry and preserving its high resistance. With this arrangement a sample of saturated air or other gas can be passed through the chamber without causing electrical leakage.

Continuous ionization of the chamber atmosphere is provided by an alpha source located within the chamber. The chamber is made one arm of a bridge circuit as shown in Fig. 2 and the ion current at a preselected voltage is compared to that in a reference chamber by an electrometer measuring circuit. The output of the electrometer is fed to a meter or recorder calibrated in terms of concentration of the detected compound and may be used to operate an alarm when a predetermined level is reached.

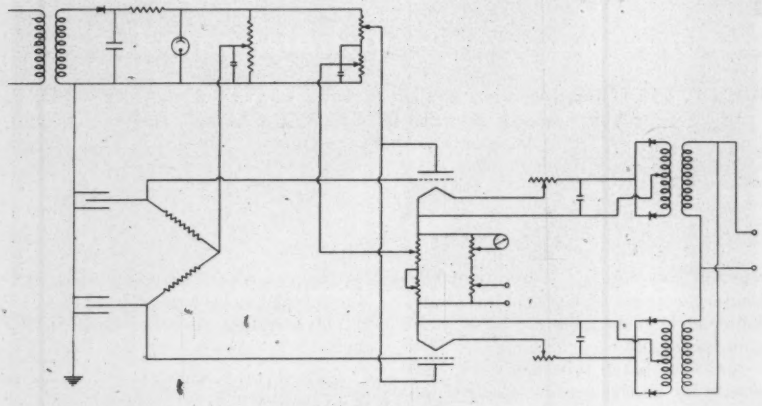

Fig. 2. Schematic diagram.

Methods of Sensitizing the Instrument

The parts per billion recorder can be sensitized for any gaseous contaminant which can be converted to particulate aerosol by a suitable reaction. For example, HF, HCl, and NO_2 are detected by reacting them with NH_3 to form a solid fluoride, chloride, or nitrate. Similarly NH_3, hydrazine, or the amines are reacted with an acid gas such as HCl or NO_2 to form particles. Figure 3 is a schematic flow diagram showing the general method employed when a gaseous reagent is used. Variations of this general scheme which connect the compensator in series flow with the detector, provide a separate clean air stream to the compensator, seal a fixed reference gas in the compensator chamber, or replace this chamber with a fixed resistor are all employed depending upon the particular gas detection problem.

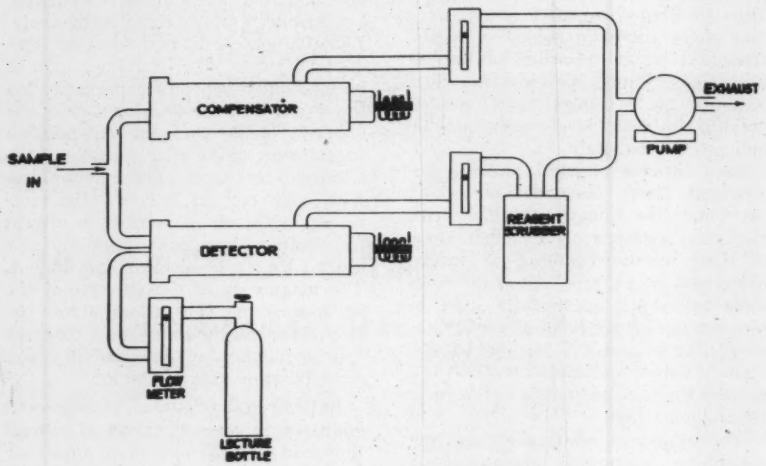

Fig. 3. Flow diagram with reagent.

Some toxic gases can be converted to particulate matter by simple pyrolysis or irradiation with ultraviolet light. Figure 4 shows a schematic of a method for detecting nickel carbonyl or tetraethyl lead. In this case the gas is converted to the metal or metallic oxide by heat. In more recent experimental work the pyrolyzer has been replaced with a UV source. With the sample correctly humidified, which apparently aids formation of favorable size particles, it has been possible to obtain full scale range for TEL of 0–20 ppb with a noise level of about ±1%.

To sensitize for halogenated hydrocarbons such as CCl_4, ethylene bromide or chloride, trichloroethylene or tetrachloroethylene, a bed of granular reagent such as copper oxide is added to the pyrolyzer. A gas-solid reaction occurs and a copper halide is formed. The copper halide is a gas at the temperature of the reaction bed but condenses to particles as it proceeds to the detector chamber. Full scale ranges

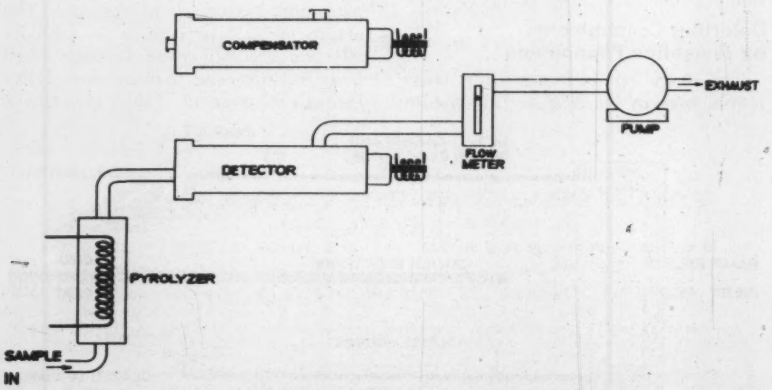

Fig. 4. Flow diagram with pyrolyzer.

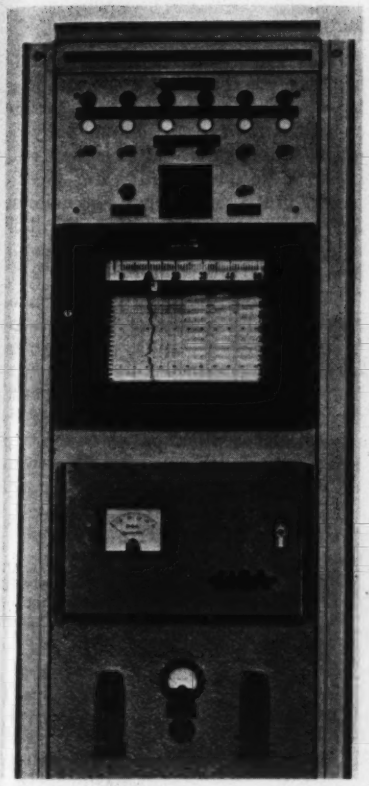

Fig. 5. Integrated air monitor and alarm system for nickel carbonyl.

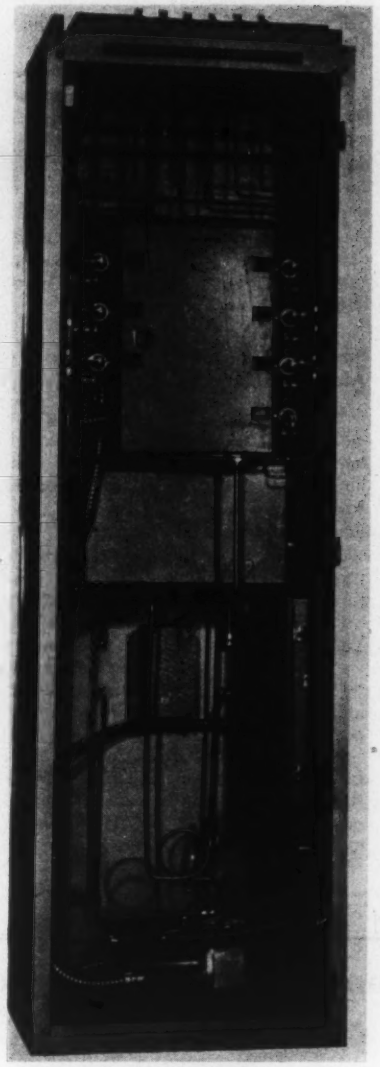

Fig. 6. View of complete instrument showing automatic sampling valve system.

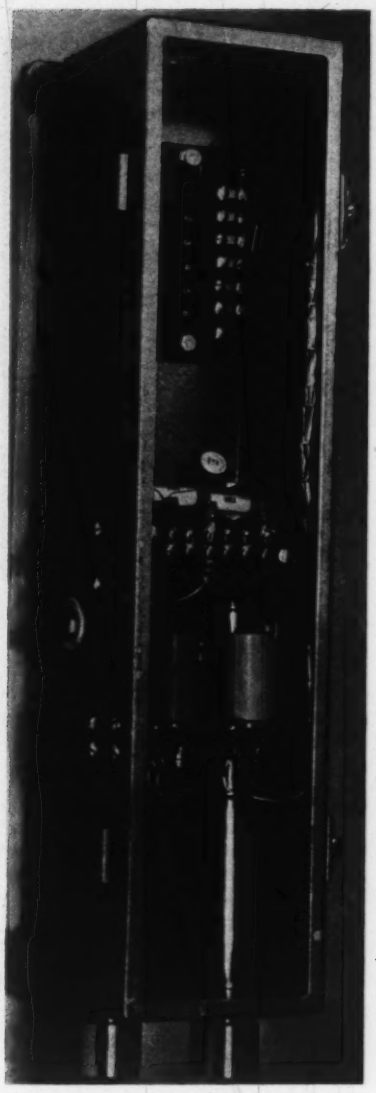

Fig. 7. Detector and electrometer compartment.

of about 0–20 ppm with 1% noise level are common for these compounds.

Instrument Response to Various Detectable Compounds

The Billion-Aire has been applied to the continuous detection and measurement of a large number of compounds. A partial list of detectable compounds and the practical full scale range for each are given in Table I. For some applications there may be more than one way to accomplish the conversion of the gas to a particulate aerosol. The preferred method is indicated.

Limitations to Applying the Detection Principle

By judicious choice of sensitization methods it is usually possible to enhance the response of the instrument to a particular contaminant and reduce interference from background constituents. However, specificity cannot always be attained, and hence each application must be treated individually. Because the instrument has a very high sensitivity to HCl when sensitized with NH_3, this compound will interfere in the detection of HF, fluorine, chlorine, and similar compounds. The response of the instrument will be a weighted sum of concentrations of all contaminants which react with NH_3 to form a

Table I—Detectable Compounds and Practical Instrument Range

Material Detected	Sensitization Method	Instrument Range
Amines	HCl or NO_2 reagent	Low ppm
Ammonia	HCl or NO_2 reagent	0–50 ppb
Hydrazine	HCl or NO_2 reagent	0–50 ppb
UDMH	HCl or NO_2 reagent	Low ppm
CCl_4	CuO converter	0–10 ppm
Ethylene Bromide	CuO converter	0–20 ppm
Ethylene Chloride	CuO converter	0–50 ppm
SO_2	CuO converter	0–10 ppm
Tetrachloroethylene	CuO converter	0–20 ppm
Trichloroethane	CuO converter	0–20 ppm
Trichloroethylene	CuO converter	0–20 ppm
Chlorine	NH_3 reagent	Low ppm
Fluorine	NH_3 reagent	0–5 ppm
Hydrogen Chloride	NH_3 reagent	0–50 ppb
Hydrogen Fluoride	NH_3 reagent	0–5 ppm
Nitrogen Dioxide	NH_3 reagent	0–10 ppm
Phosgene	NH_3 or CuO	Estimate ppm
Nickel Carbonyl	Pyrolysis or UV radiation	0–50 ppb
Tetraethyl Lead	Pyrolysis or UV radiation	0–50 ppb

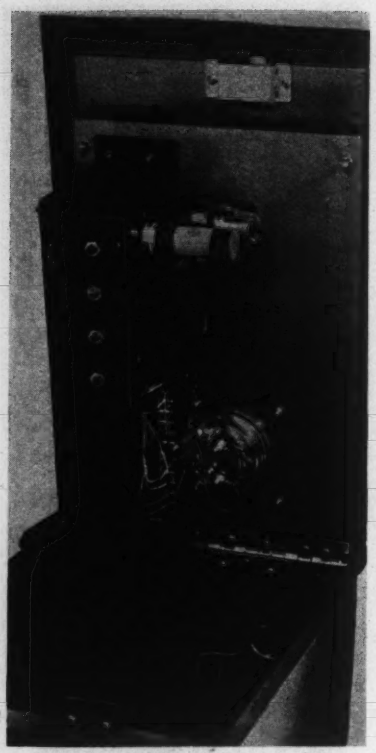

Fig. 8. Power supply and control box.

solid product. Similarly, when the instrument is sensitized with HCl or NO_2 the response is a summation of the deflections obtained from the individual alkaline substances present.

Fortunately when applying the monitor to control of air pollution at the source or to the surveillance of plant atmospheres for the protection of industrial personnel and property, the probability of background interference is greatly decreased. Furthermore from the standpoint of detection of a hazardous condition, the lack of resolution between HF and F_2, for example, is not a serious limitation.

Integrated Air Monitor and Alarm Systems

Figures 5 and 6 show a complete instrument and sampling system for monitoring six sampling points for nickel carbonyl. The sample is drawn continuously from each point by the integral pumps and the samples are successively fed to the detector by a programmed valving system. A continuous record of the concentration at each point is provided. An audible alarm signal is given when the concentration at any point reaches a preselected level and annunciator lights indicate the area in which the high concentration has occurred.

Figure 7 shows the internal construction of the detector and electrometer tube compartment. The interior of the power supply and control box are seen in Fig. 8.

Summary

High sensitivity, continuous recording, and instantaneous response for a large number of noxious or toxic air contaminants can be obtained by a unique combination of chemical and physical detection principles. Sensitivities in the range of parts per million are usually obtained with ease. For many compounds, a full scale range for less than 100 ppb is quite feasible.

The method is not completely specific, although enhancement of the response to one compound in a mixture can usually be attained. Each application should be studied carefully to take advantage of all discriminating techniques and summation of co-existing toxic contaminants when practical from the viewpoint of hazard.

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GAS CHROMATOGRAPHIC ANALYSIS *of Incinerator Effluents**

WILLIAM N. TUTTLE, Analytical Instrument Specialist, and
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Bay Area Air Pollution Control District, San Francisco, Calif.

Proposed regulations of the Bay Area Air Pollution Control District included emission standards for C_2 to C_6 hydrocarbons from incinerator effluents. The proposed regulation states that the total C_2 and C_6 hydrocarbon concentration should not exceed 50 ppm measured at standard conditions. The proposed regulation further states that the concentration of hydrocarbons should be measured by gas chromatography.

Many reports have appeared in the literature relating to the hydrocarbon content of incinerator effluents.[1, 2, 3, 4] Methods which have been used to measure hydrocarbons from these sources include Orsat analysis, infrared analysis, and mass spectrometry. It was felt that the application of gas chromatographic techniques would afford a procedure which would shed light on the quantity and nature of individual hydrocarbons present in incinerator effluents. This paper is concerned with the analysis, by means of gas chromatography, of low molecular weight hydrocarbons present in such effluents.

Apparatus and Equipment

1 Beckman GC-2 chromatograph and MH O-1 mv recorder.
2 35-liter stainless steel sampling tanks.
3 Gases, Matheson, 99% pure.
4 Ascarite.
5 Tygon tubing.
6 Liquid nitrogen.
7 Drierite.
8 Vacuum gauges.
9 Syringes, Micro and Luer-Lok.
10 Swagelok quick-connect fittings.

Description of Apparatus

The model GC-2 Beckman Chromatograph was modified to permit the concentration of hydrocarbons by freezing in an auxiliary trap.[5, 6, 7] This is shown schematically in Fig. 1 and in the photograph shown as Fig. 2. Using this modification, it is possible to freeze out the hydrocarbons from a relatively large volume of sample.

The analytical column helium supply line between the pressure reducing capillary and the gas sampling valve was replaced with 1/4 in. copper tubing, Swagelok fittings, Hoke 450 Series Toggle valves, and pyrex glass "U" tube ascarite traps as shown in Fig. 1. A Swagelok "Tee" was included before the trapping column for syringe injection. Swagelok "Quick-Connect" fittings are used on the trapping columns to facilitate easy changing.

The trapping columns are 1/4 in. copper tubing 18 in. to 24 in. in length bent into a "U." The bottom 6 in. to 8 in. is filled with the analytical column packing material.

Two analytical columns were used to differentiate C_2 through C_6 hydrocarbons. A 25 ft hexadecane column was used for the analysis of C_2, C_3, and C_4 hydrocarbons. A 5 ft hexadecane column was used for the analysis of C_5 and C_6 hydrocarbons. Both column packings are approximately 28% hexadecane on C-22, 42–60 mesh firebrick. Both columns were operated at 40°C and 30 psig. The flow rates were approximately 45 cc/min. for the 25 ft column and 72 cc/min. for the 5 ft column.

Collection Procedure

Samples of effluent are collected in stainless tanks equipped with vacuum gauges as reported earlier.[4]

Analytical Procedure

The volume of sample required for an analysis varies with the concentration of hydrocarbons present in the sample. For multiple chamber incinerators equipped with afterburners, it is necessary to use from 10 to 20 liters of effluent in order to obtain a satisfactory trace. For single chamber incinerator effluents containing large quantities of hydrocarbons, as little as 100 ml. of effluent is adequate to give a satisfactory trace.

The 35-liter tank of effluent is connected through an ascarite-drierite trap to the trapping system, and the trapping column is immersed in liquid nitrogen. The vacuum pump is started, and the approximate desired volume of sample is permitted to flow through the trapping column at a rate of 1 to 2 lpm. After completion of the trapping run, the pump is disconnected from the line, and the sampling tank is removed. The volume of sample passed through the trapping column is calculated by measuring the pressure of the sample tank before and after the trapping run with a sensitive vacuum gauge.

All tank samples are passed through a large ascarite-drierite trap at the inlet of the trapping system to remove water, carbon dioxide, and oxygenated hydrocarbons in order to prevent interferences with the chromatogram of the low molecular weight hydrocarbons by these materials. Samples and standards injected by syringe have these materials removed by the small ascarite traps on each side of the trapping column.

An outside source of helium is connected to the trapping system and helium is allowed to flow at 1 to 2 lpm for 10 to 15 minutes (with the trapping column still in liquid nitrogen), to flush most of the nitrogen and oxygen out of the system. After the flushing operation is complete, the trapping column is sealed off by closing the inlet and outlet valves of the trapping system. The valves permitting the flow of analytical column carrier helium through the trapping column are opened and carrier helium is permitted to run through the trapping column, which is still immersed in liquid nitrogen.

When a satisfactory base line is observed on the recorder, the trapping column is removed from the nitrogen and immersed in a bath of water at room temperature. It is essential that the exchange of baths be done quickly to

* Presented at 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

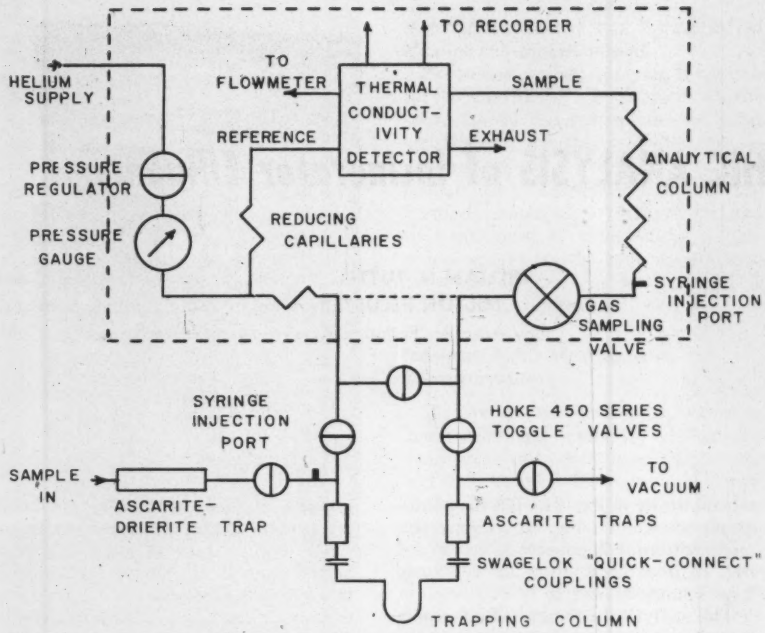

Fig. 1. Schematic diagram of trapping system & GC-2.

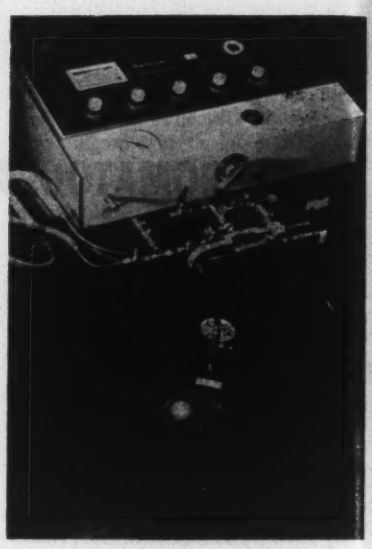

Fig. 2. Trapping system for concentrating C_2 to C_6 hydrocarbons present in incinerator effluents.

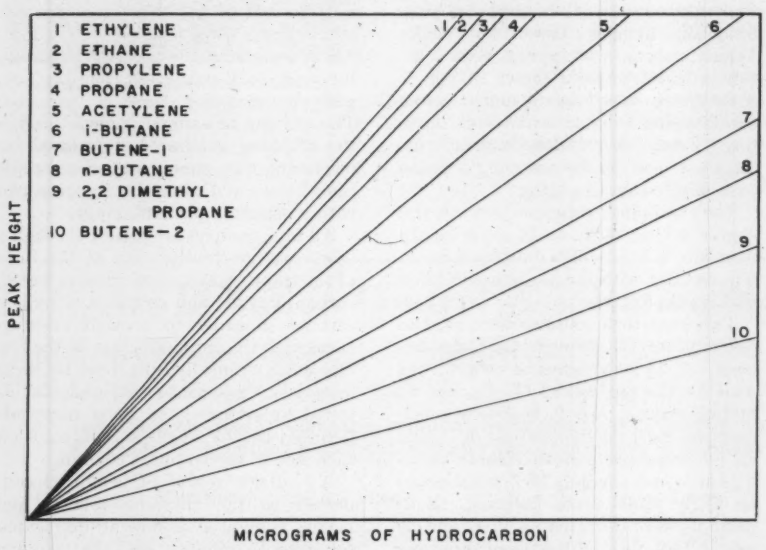

Fig. 3 Hydrocarbon calibration curve.

permit the rapid elution of trapped hydrocarbons from the trapping column to the analytical column, and the analysis proceeds as usual.

Calibration

Calibration of the instrument with known quantities of hydrocarbons was accomplished as follows: a known volume of hydrocarbon was injected into the sampling port upstream from the trap. Injections with pure gas were made with micro-syringes and diluted samples of gas with luer-lok syringes. During the injection of a standard, carrier gas was permitted to flow through the trapping column, which was immersed in liquid nitrogen, until a satisfactory base line was obtained. The nitrogen was then removed and replaced with a beaker of hot water. The chromatogram was recorded, and the process repeated for varying concentrations of standard gas. Calibration curves were constructed relating peak height or area and concentration. These are shown in Fig. 3.

It is interesting to note that, after the injection of a volume of air-diluted standard gas into the trapping column at the same time that carrier gas is flowing through the system, the air peak appears on the recorder indicating that air (oxygen and nitrogen) is not completely held in the trap. Replacement of the cold bath with water after a base line is established releases the trapped hydrocarbons along with a residual quantity of "air." This residual gas is recorded as the first peak to leave the separating column and may be used as a time marker from which to measure the times of other peaks. This is shown in Fig. 4.

It is also interesting to note that methane is not quantitatively trapped by this procedure. If present in small quantities, it is usually flushed from the trap. If present in large quantities, it appears as a side peak on the residual gas peak mentioned above. Methane analyses, when required, were performed on an aliquot of the original effluent by infrared absorption.[4]

Discussion

The effluents from a series of incinerators were analyzed according to the procedure described. Particular emphasis was placed on the separation and quantitation of acetylene, ethylene, and ethane. The chromatographic tracings for C_3, C_4, C_5, and C_6 hydrocarbons were of interest only insofar as their total concentrations were concerned and these were generally much lower in concentration than the C_2 compounds. Total hydrocarbons were calculated by adding the individual hydrocarbon concentrations. Table I shows the results of these analyses.

An inspection of Table I indicates that methane, ethylene, and acetylene are present in most incinerator effluents. Generally, when the concentration of ethylene or acetylene is below 10 ppm the concentration of C_3 and higher hy-

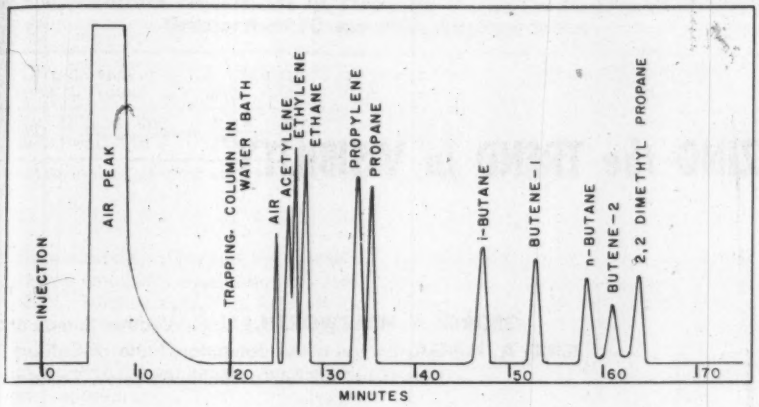

Fig. 4. Typical hydrocarbon chromatogram.

Table I—Gas Chromatographic Analysis of C_2 to C_6 Hydrocarbons in Incinerator Effluents

Test No.	Type[a]	Concentration, ppm: Acetylene	Ethylene	Ethane	C_3	C_4	C_5	C_6	Total C_2 to C_6 Hydrocarbons	Methane[b]
1	A	0.8	8	0.3	—	—	—	—	9	15
2	A	1.5	9	0.3	0.5	—	—	—	11	10
3	A	0.9	8	0.3	0.3	—	—	—	9	15
4	A	2	3	0.6	—	—	—	—	6	30
5	B	711	2175	425	375	120	250	75	4100	9000
6	A	—	3	—	—	—	—	—	3	5
7	B	247	122	—	3	3	—	—	375	3000
8	B	341	482	32	25	4	2	—	886	3000
9	A	2	6	1	1	—	—	—	10	10
10	A	—	4	—	—	—	—	—	4	2
11	B	59	129	3	—	—	—	—	191	500
12	A	—	5	—	—	—	—	—	5	10
13	A	—	12	—	—	—	—	—	12	25
14	B	800	3100	500	450	175	275	120	5420	9000
15	B	600	2300	300	220	120	180	90	3810	7000

[a] A = Adequately designed multiple chamber incinerator. B = Inadequately designed incinerator.
[b] Infrared analysis.

Table II—Gas Chromatographic Analysis of Some C_4 to C_6 Hydrocarbons Present in Incinerator Effluents

Compound	Test No. 1	2	3	4	5
	Type of Incinerator[a]: B	B	B	B	B
	Concentration, ppm				
Total C_2 compounds	3321	4400	3200	855	369
n-butane	35	70	20	—	—
i-butane	—	20	—	4	2
C_4H_8[b]	150	160	105	5	1
3 methyl butene-1	30	50	20	2	—
Pentene-1	25	40	12	—	—
n-pentane	48	85	30	—	—
2 methyl butene-2[c]	58	75	17	—	—
2 methyl pentane	56	77	50	—	—
3 methyl pentane	6	15	10	—	—
n-hexane	3	12	5	—	—

[a] B = Inadequately designed incinerator.
[b] This peak includes: butene-1, isobutylene, butadiene 1,3, ethyl acetylene.
[c] This peak includes: 2 methyl pentene-1.

drocarbons is less than 1 to 2 ppm.

Effluents which contained large quantities of methane, ethylene, and acetylene usually contained relatively high concentrations of C_2 to C_6 hydrocarbons.

While the primary purpose of this investigation was to determine the total hydrocarbon concentration in the C_2 through C_6 range, it was of interest to determine the nature and quantities of some of the C_4 through C_6 compounds which were present in incinerator effluents. It should be pointed out that these were measurable only in the effluents from single chamber incinerators or multiple chamber incinerators with the afterburners turned off. Table II shows the results of analyses on several such incinerators. It is apparent from the table that appreciable quantities of hydrocarbons, which play a role in the photochemical formation of smog,[5, 9, 10] are present in such effluents.

No general conclusions concerning the significance of these results in relation to the photochemical formation of smog can be drawn until a sufficient number of samples have been analyzed. This sampling program is currently in progress by the District.

Conclusions

A procedure for the gas chromatographic analysis of incinerator effluents has been described and has been used to analyze the effluents from a series of incinerators. Results indicate that, when the concentration of C_2 hydrocarbons is below 10 ppm, the C_2 to C_6 hydrocarbons are generally present in less than 1 to 2 ppm. When the C_2 hydrocarbons are present in high concentrations, the C_4 to C_6 compounds are generally present in significant concentrations. Some specific C_4 to C_6 compounds found in the effluents from incinerators have been identified.

The standard of 50 ppm of C_2 to C_6 hydrocarbons in incinerator effluents appears to be a satisfactory emission standard since it adequately differentiates between incinerators which are well designed and operated and those which are not.

Acknowledgment

The authors wish to acknowledge the helpful comments and suggestions of John E. Yocom, Director of Technical Services, Bay Area Air Pollution Control District.

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(*Continued on p. 467*)

A METHOD *for* ANALYZING *the* TREND *in* VISIBILITY*

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Initially this study was undertaken to determine the visibility trend in the Central Valley of California. However, the method of trend analysis that was developed appeared suitable for application to other locations. Subsequently, visibility data for Los Angeles, Calif., were subjected to the same method of analysis.

Solid and liquid particulate materials, which reduce visibility when suspended in the atmosphere, represent air pollution. Such particles are often associated with human activity and the emission of wastes into the air over communities. While smokes and dusts are frequently the major sources of particulate matter, aerosols formed in the "photochemical" type of air pollution experienced in California metropolitan areas can also reduce visibility.[1] Consequently, in the absence of naturally occurring aerosols, visibility measurements may be interpreted as measurements of man-induced air pollution.

Because of the serious air pollution problem in the large metropolitan regions along the California coast there is a concern that similar problems may develop in the larger cities of the Central Valley, which in recent years have been growing rapidly. Many residents of the Central Valley have voiced the opinion that there has been a decrease in visibility, and that haze and smoke are observed more often than in past years.

It is to be expected that air pollution levels are rising in this portion of the State since there has been a large growth in the major population centers as well as in the Central Valley as a whole. In the fall of 1957 the State Department of Public Health, together with a number of local health departments in the Central Valley, inaugurated an oxidant and smoke sampling program to evaluate present levels of air pollution. At Sacramento in 1957 there were several days when eye irritation and elevated oxidant values were observed.[2] The University of California at Riverside and the Agricultural Extension Service of the University have found evidence of "oxidant" type damage to vegetation in some of the Central Valley counties.[2]

Since pollutant measurements and vegetation damage observations are available for only a short period it has not been possible to determine trends in air pollution levels. Visibility observations over a period of years, however, are available for several U. S. Weather Bureau valley stations. Such observations have been analyzed to determine if there has been a trend of decreasing visibility. The effect of wind speeds and directions on visibility have also been considered. This work follows that of a less detailed pilot study.[3]

Visibility Observations

U. S. Weather Bureau regular hourly weather observations, taken at Sacramento Municipal Airport and Kern County Airport on the outskirts of Bakersfield, were used to study trends in visibility. These locations were selected because of availability of data and because the observation sites had not changed over the years studied. Only daytime observations, about 0730–1730 PST, were considered since visibility at night depends upon different factors and generally is less reliable.[4] Thus there were 11 observations per day. May, July, September, and November were selected to span the usual months when air pollution is more likely to occur. Sacramento data were available for 1935–58, except that about six years through the war were missing. There is no reason to suspect that these missing data would materially affect the conclusions reached. At Bakersfield the years 1948–57 have been studied.

Since 1943 Weather Bureau observers have reported visibility as "the lowest visibility over the half of the horizon with the greatest visibility." Prior to that time visibility was defined as "the greatest distance toward the horizon that known objects can be identified." Summaries for this study do not suggest that this change in definition had any noticeable effect on Sacramento observations.

Natural aerosols which usually limit visibility include fog and precipitation. Precipitation may occur at various relative humidities but natural fog is unlikely with humidities lower than about 90%. Visibility observations with precipitation and/or relative humidity greater than 90% were not used in order to eliminate observations when natural aerosols could have reduced the visibility. Actually these conditions seldom occurred, and at both sites all months considered except November were typically dry (especially during daytime), as shown in Table I. November climates varied from year to year, sometimes being in the rainy season and sometimes in an extension of the dry summer conditions. Even observations with relative humidities above 70% and/or precipitation were rare except in November.

Discussion of Data

The data were tabulated by the percent frequencies that monthly visibilities were in the ranges 0–10, 11–19, 20–30, and greater than 30 miles. These ranges were chosen somewhat arbitrarily, although consideration was given to the desirability of having relatively large samples in most ranges and

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* Presented at the 53rd Annual Meeting of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

† While on assignment through the U. S. Public Health Service to the State of California, Department of Public Health.

Table I—Percent Frequencies of Precipitation and/or Relative Humidities Greater than 70 and 90%, Daylight Hours

Precip. and/or Rel. Hum.	Bakersfield (10 years) May	July	Sept.	Nov.	Sacramento (18 years) May	July	Sept.	Nov.
Rel. Hum. >90%	1.3	0.1	0.1	8.2	2.6	0.2	0.8	16.3
Rel. Hum. >70%	2.9	0.1	1.0	23.6	—	3.3[a]	—	39.8[a]

[a] Based on 12 years of record.[3] May and September not available.

to the desirability of keeping the number of ranges small but consistent with the over-all visibility ranges at both sites. For sites where visibility characteristics are different from those in this study it is likely that different ranges would be more appropriate. The percentages for each of the ranges were plotted against time (years), and a linear trend line was fitted to each set of data by the method of least-squares. Figure 1 is such a plot for the Bakersfield and Sacramento observations in May. Since at each site the relative nature of the trend lines is generally similar between months for corresponding visibility ranges, the trend lines for the other three months are not shown. However, these may be readily determined by reference to Tables II and III where the "Net Changes" are directly proportional to the trend line slopes. The Bakersfield trend lines indicate that the percent frequencies of poorest visibilities, 0 to 10 miles, increased with time in all four months. The frequencies of best visibilities, greater than 30 miles, decreased, except in July when a very slight upward trend occurred. From a consideration of the two extreme visibility ranges it appears that Bakersfield visibility has declined; the frequencies of visibilities in the lower range increased while those in the upper range decreased. However, the two intermediate visibility ranges do not at first seem to support this conclusion. All four months showed a decline in the frequency of 11 to 19 mile visibilities. An increasing trend occurred in the 20 to 30 mile visibility range, except for September where the slope was slightly downward.

Table II—Schematic Shift with Time (Based on Least-Squares Linear Trend Lines) of Bakersfield Visibility Shift from One Range to Another in Percent Frequency

Visibility Range, miles	Frequency, % 1948	1957	Net Change, % 1948 to 1957	+	Resultant Shift, %, Between Visibility Ranges
			May		
>30	15.7	0.4	−15.3	+	0 = −15.3
20–30	50.7	60.6	+ 9.9	+	−15.3 = − 5.4
11–19	27.2	18.2	− 9.0	+	− 5.4 = −14.4
0–10	6.4	20.8	+14.4	+	−14.4 = 0
			July		
>30	2.4	3.4	+ 1.0	+	− 1.0 = 0
20–30	36.6	46.9	+10.3	+	−11.3 = − 1.0
11–19	47.3	27.5	−19.8	+	0 = −11.3
0–10	13.7	22.2	+ 8.5	+	− 8.5 = 0
			September		
>30	2.7	0.0	− 2.7	+	0 = − 2.7
20–30	25.1	21.5	− 3.6	+	− 2.7 = − 6.3
11–19	43.3	30.7	−12.6	+	− 6.3 = −18.9
0–10	28.9	47.8	+18.9	+	−18.9 = 0
			November		
>30	8.1	0.0	− 8.1	+	0 = − 8.1
20–30	19.8	23.2	+ 3.4	+	− 8.1 = − 4.7
11–19	23.1	6.9	−16.2	+	− 4.7 = −20.9
0–10	49.0	69.9	+20.9	+	−20.9 = 0

At Sacramento the trend lines show that the frequencies of poorest visibilities, 0 to 10 miles, increased in all four months. In the next to the best visibility range, 20 to 30 miles, the frequencies decreased. For each month the largest trends (steepest slopes) are in the 0 to 10 and 20 to 30 mile ranges. In May and November the changes indicated by the trend lines for the visibility ranges of 11 to 19 miles, and greater than 30 miles, are practically negligible. At Sacramento, where the stronger trend lines indicate increasing frequencies in the poorest visibility range and decreasing frequencies in the next to the best visibility range, there is a somewhat clearer indication of a general visibility decline than at Bakersfield.

It is important to consider what visibility changes are likely to result in a trend of deteriorating visibility. For each set of data the total visibility frequency must be 100%. Consequently, a frequency change in any one of the given visibility ranges must be compensated by changes in the frequencies of the other ranges. When visibility changes from, say, 25 to five miles, it passes through intermediate values—such changes are not discontinuous. Therefore, with a trend of deteriorating visibility the resultant frequency changes (with time) in given visibility ranges are shifting toward each next lower visibility range.

The resultant shifts between visibility ranges as determined from the least-squares linear trends are schematically traced in Tables II and III for Bakersfield and Sacramento. For instance, in Table II, May, the frequency of visibilities greater than 30 miles declined from 15.7% in 1948 to 0.4% in 1957, a net change of minus 15.3%. This minus 15.3% is shifted to the next lower visibility range, 20 to 30 miles, where it is added to a plus 9.9% net change in the frequency of 20 to 30 mile visibilities from 1948 to 1957. Adding minus 15.3 and plus 9.9 leaves minus 5.4%. This resultant minus 5.4 shifts to the next lower range, 11 to 19 miles, where it is added to a minus 9.0 net change in the frequency 11 to 19 mile visibilities from 1948 to 1957. The resultant sum is minus 14.4% which, shifted to the next lower visibility range, 0 to 10 miles, accounts for the observed net change of plus 14.4% from 1948 to 1957.

As shown in Table II, except for July, the resultant changes in percent frequencies of visibilities in given ranges are all shifting toward each next lower visibility range. Thus at Bakersfield in May, September, and November there is an apparent trend of deteriorating visibility. The July trend is more difficult to evaluate. Although the frequency of 0 to 10 mile visibilities has increased, so have those in the ranges

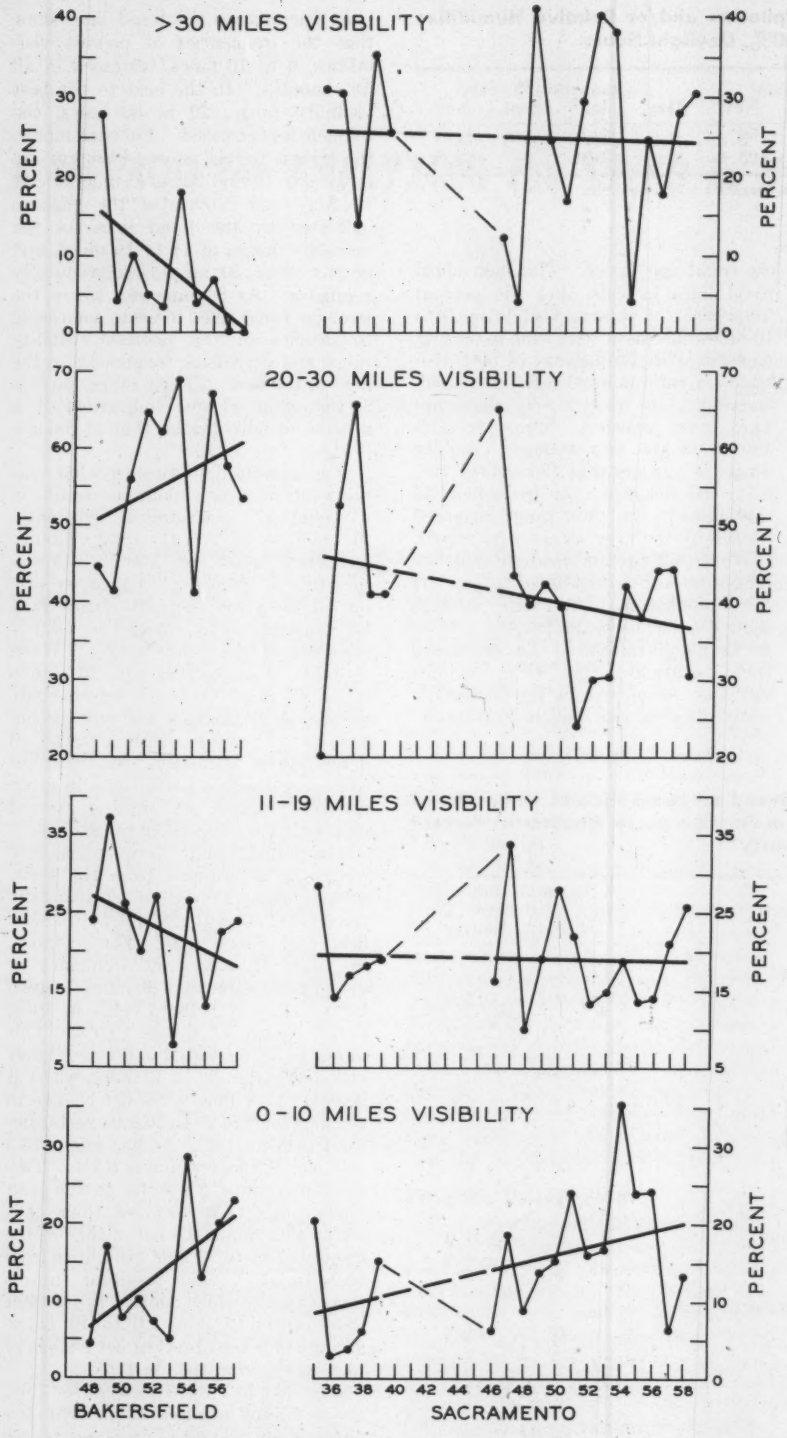

Fig. 1. Percent frequencies that visibilities were in given ranges at Bakersfield and Sacramento, Calif., during May. Linear trends (heavy lines) were computed by the method of least-squares. Note: In the part of the figure depicting 11–19 mile visibilities for Sacramento the dashed line connecting the years 39 to 47 is incorrect; the dashed line should connect 39 to 46.

of 20 to 30 and greater than 30 miles. These increases are all accounted for by a decline in the frequency of 11 to 19 mile visibilities. The resultant shift downward to 0 to 10 mile visibilities, 8.5%, almost equals the total resultant shift upward to the two highest visibility ranges, 12.3%. Since the resultant shift of visibility frequencies upward to higher ranges nearly equals that downward to lower ranges, it does not appear that there is a meaningful over-all trend in the July visibility at Bakersfield.

Table III for Sacramento shows that in all four months studied there is a resultant shift of visibility frequencies downward to lower visibility ranges. September and November are slight exceptions in that there were small increases in the frequencies of visibilities greater than 30 miles. However, these were more than compensated for by other shifts downward.

As mentioned, the net changes in Sacramento visibilities of 11 to 19 miles and greater than 30 miles were particularly small during May and November. Apparently in these months visibilities greater than 30 miles did not participate in the over-all trend. The slight changes in the 11 to 19 mile visibility range suggest that the shifts downward to this range from the 20 to 30 mile range were about equal to the shift downward to the 0 to 10 mile range from the 11 to 19 mile range.

The data presented indicate that there has been a general trend of deteriorating visibility at both Bakersfield and Sacramento. It would be desirable at this point to present statistical evidence that the trends are not likely due to chance. However, as a whole such attempts have not been successful. This does not necessarily mean that the trends are unreal. A part of the difficulty in applying statistical tests lies in the inherent nature of visibility data. For instance, of the 32 least-squares trend lines, the slopes of 20 are considered relatively large. The trend lines were tested for significance from zero slope.[5] Only six of these slopes are statistically significant from zero at the 90% confidence level. Referring again to Fig. 1, the reason for this is readily apparent; it is the high degree of scatter about the computed trend lines. Large variations in visibility from year to year are not at all unusual. Such variations are considered a likely consequence of the various complex and interacting factors that affect visibility. Some of these factors are: the general ability of the atmosphere to dilute contaminants; the effect of weather, such as wind and precipitation on various open burning practices; space-heating requirements; varying pollutant emissions from industrial, commercial, and other sources, the locations of which have varied relative to the visibility observation sites, to mention a few. In addition the nature of visibility observations should be pointed out. Although visibilities are estimated by trained observers, they are subjective, and this factor likely has contributed to the year to year fluctua-

Table III—Schematic Shift with Time (Based on Least-Squares Linear Trend Lines) of Sacramento Visibility Shift from One Range to Another in Percent Frequency

Visibility Range, miles	Frequency, % 1935	1958	Net Change, %, 1935 to 1958		Resultant Shift, %, Between Visibility Ranges
			May		
>30	25.7	24.3	− 1.4	+	0 = − 1.4
20–30	45.9	36.7	− 9.2	+	− 1.4 = −10.6
11–19	19.7	18.8	− 0.9	+	−10.6 = −11.5
0–10	8.7	20.2	+11.5	+	−11.5 = 0
			July		
>30	19.1	11.4	− 7.7	+	0 = − 7.7
20–30	61.5	38.3	−23.2	+	− 7.7 = −30.9
11–19	18.0	25.4	+ 7.4	+	−30.9 = −23.5
0–10	1.4	24.9	+23.5	+	−23.5 = 0
			September		
>30	5.0	10.6	+ 5.6	+	− 5.6 = 0
20–30	37.7	23.5	−14.2	+	− 5.6 0 = − 8.6
11–19	29.8	20.4	− 9.4	+	− 8.6 = −18.0
0–10	27.5	45.5	+18.0	+	−18.0 = 0
			November		
>30	11.9	13.9	+ 2.0	+	− 2.0 = 0
20–30	22.9	12.6	−10.3	+	− 2.0 0 = − 8.3
11–19	13.3	13.2	− 0.1	+	− 8.3 = − 8.4
0–10	51.9	60.3	+ 8.4	+	− 8.4 = 0

tions. However, there is no reason to suspect that this subjectivity has varied in a systematic manner. Another factor affecting the significance of the trend line slopes from zero is the length of time considered. It would be expected that with a considerably longer span of data, more of the slopes would differ significantly from zero.

As a whole, it is believed that a general trend of deteriorating visibility at Bakersfield and Sacramento is more real than has been shown by rigid statistical tests. This is inferred from the similarities between months in the respective trend lines at each site. For example, at Sacramento in each month the relatively large visibility percent frequency changes (Table III), that result from steep trend line slopes and that account for most of the over-all visibility trend, are in the 0 to 10 and 20 to 30 mile visibility ranges. Although, statistically, few of these trend line slopes differ significantly from zero, in each of the four months studied the 0 to 10 mile slopes are all positive, resulting in large percent frequency increases. The 20 to 30 mile slopes are all negative, resulting in large percent frequency decreases.

At Bakersfield the 0 to 10 mile visibility trend line slopes and frequency changes (Table II) are all positive and relatively large. In the 11 to 19 mile visibility range the slopes are negative and the frequency changes are large. Except in May and July the frequency changes in 20 to 30 mile visibilities are relatively small. Again omitting July, the greater than 30 mile visibility trend line slopes are negative, although in September the slope is small. Probably the July trend lines should not be compared with those for other months since it was concluded that as a whole there was little meaningful trend to the visibility in this month.

Effect of Wind Speed and Direction

For each visibility observation a wind observation at the respective sites was available. Table IV is a summary of the percent frequencies of 0 to 10 mile visibilities by wind speeds. Thus at Bakersfield, with calm conditions, the visibility was 0 to 10 miles 50.6% of the time. This table shows that the frequencies of poor visibilities, 0 to 10 miles, at first decrease with increasing wind speeds, and then increase with stronger winds. These variations are interpreted as due to increasing atmospheric dispersion of pollutants with increasing wind speeds up to about 15 to 20 mph. Then where the wind becomes strong enough to pick up loose materials, such as dust and dirt, the earth's surface acts as a source for such visibility-reducing particulates. The data in Table IV indicate this latter mechanism begins to operate at wind speeds exceeding 15 mph at Bakersfield and above 20 mph at Sacramento. In the data used here these high wind speeds occurred infrequently, in 3.4% of the observations at Bakersfield and 5.8% at Sacramento.

Kern County Airport, near the edge of town, is about four miles north-northwest from downtown Bakersfield. Sacramento Municipal Airport, located on the southern city limit, is about $4^1/_2$ miles from the downtown area. With these urban areas so close to the observation sites it seemed likely that airport visibilities would be adversely affected by nearby contaminant emissions. Such effects would of course be more likely with air flow from urban directions as opposed to air movement from rural directions. Accordingly, wind directions were divided into urban and rural. For Kern County Airport, urban wind directions were defined as blowing from the sector east-southeast clockwise through west (ESE-W) and rural directions were defined as from west-northwest through east (WNW-E). Actually most of the nearby Bakersfield population lies in the sector east-southeast through south but this area was extended through west to include some scattered oil field operations. The nearby rural direction is relatively unpopulated.

For Sacramento it is estimated that more than 90% of the metropolitan population lies in the sector northwest clockwise through east-southeast (NW-ESE) relative to the airport, and such wind directions were designated as urban. The southeast through west-northwest (SE-WNW) sector was designated as rural.

It should be pointed out that instantaneous wind directions do not necessarily represent true trajectories of air parcels. However, because of the short travel distances involved, such an assumption was considered permissible.

Table V gives the percent frequencies of 0 to 10 mile visibilities by wind directions for 1 to 10 mph wind speeds. Only 1 to 10 mph wind speeds have been used since our intent here is to determine an effect on visibility due to air flow from over nearby urban pollutant source areas. For stronger wind speeds the same relationships are not necessarily expected to hold true because of the

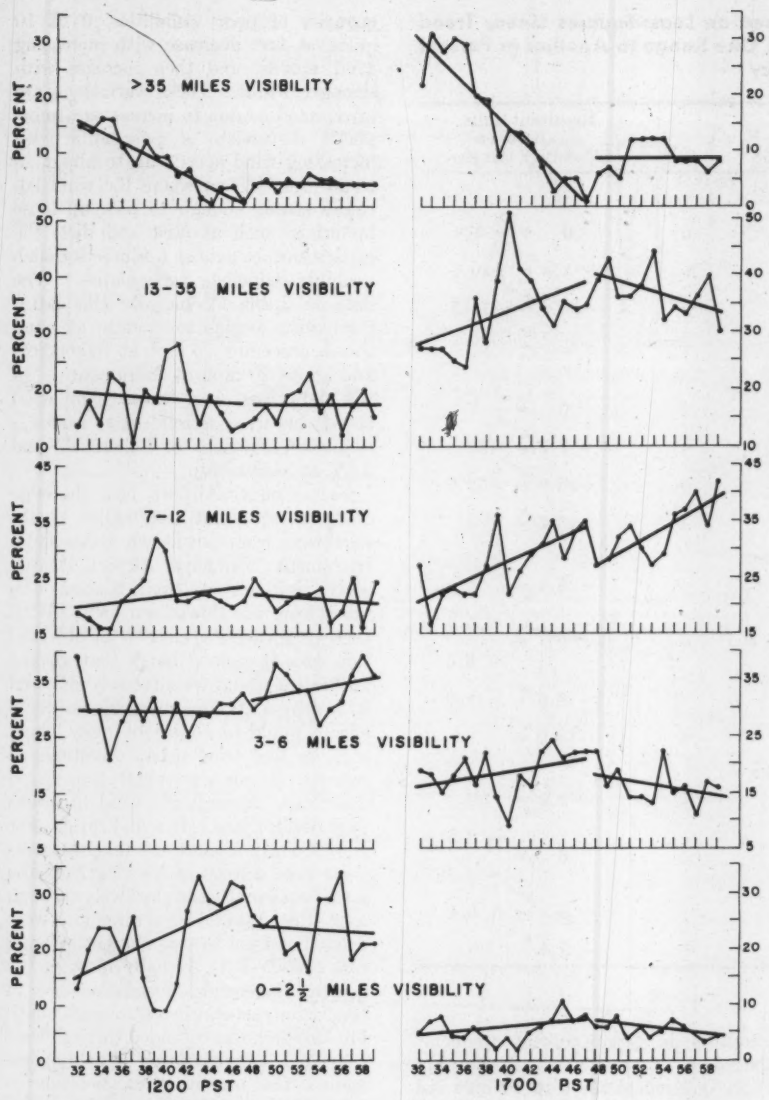

Fig. 2. Percent frequencies that visibilities were in given ranges at downtown Los Angeles, Calif., yearly values for 1200 and 1700 PST. Linear trends (heavy lines) were computed by the method of least-squares.

wind action mentioned in the discussion of Table IV.

Table V shows that at both the Bakersfield and Sacramento airports poor visibilities, 0 to 10 miles, are more likely with light air movement from over the nearby urban areas than from rural directions. A statistical test[6] indicates that at both sites the differences in frequencies of poor visibilities by air flow (Table V) are significant at a very high confidence level. Actually the data of Table V probably underestimate such differences, which likely would be even more striking if actual air trajectories were considered and if the most urban directions were compared to the most rural directions.

As indicated by Tables IV and V the wind conditions more favorable to poor visibilities are calm and from urban directions for one to 10 mph speeds. Because of this relationship the trends in wind conditions favoring poor visibilities were investigated. For each site the two wind conditions mentioned above were combined into a single percent frequency for each month of each year, to which least-squares linear trend lines were fitted. These trend lines were then tested for a statistically significant difference from zero slope.[5] For all four months at Sacramento none of the slopes is significantly different from zero at the 90% confidence level. Except in November the slopes are negative. These slopes are relatively slight, varying from −0.24 to +0.14.

At Bakersfield the slopes of the trend lines for wind conditions favoring poor visibilities vary from +0.55 to +1.34. The largest slope occurs in

Table IV—Percent Frequencies of 0–10 Mile Visibilities by Wind Speeds—May, July, September, and November

Wind Speed, miles/hr	Bakersfield[a]	Sacramento[b]
Calm	50.6	65.2
1–5	35.7	50.4
6–10	26.6	28.8
11–15	13.2	12.7
16–20	15.7	10.7
>20	63.6	15.5
All	31.6	29.4

[a] 1948–57.
[b] 1935–38 and 1946–58 plus May and July, 1939, and July, September, and November, 1945.

November and is the only one that is significantly different from zero at the 90% confidence level. The possibility that the trend of wind conditions especially favorable to poor visibilities has contributed to the over-all visibility trend in November at Bakersfield, therefore, cannot be discounted.

Application of Trend Analysis Method to Los Angeles

Using U. S. Weather Bureau observations for downtown Los Angeles, California, the 1932–54 visibility trend has been studied by Neiburger.[7] Neiburger has concluded that since 1947 and 1948, when controls were put on certain smoke, dust, and sulfur dioxide emissions, there seems to have been an improvement in visibility. Table VI of Neiburger's report, which gives by years the percent frequencies that visibilities were in the ranges 0–2½, 3–6, 7–12, 13–35, and more than 35 miles, was extended through 1959. The entire record, 1932–59, was divided into two parts: 1932–47, before controls were put on certain emissions, and 1948–59, after such controls. For each visibility range least-squares linear trend lines were computed separately for the two periods, and are shown in Fig. 2 for the yearly 1200 and 1700 PST observations. From the initial and terminal points of the trend lines the net percentage changes were determined. These and the resultant shifts between visibility ranges were traced as shown in Table VI. For the earlier period, 1932–47, at both 1200 and 1700 PST a trend of declining visibility is indicated. The resultant shifts between visibility ranges are all downward to lower visibilities and the total downward shifts are relatively large,

Table V—Percent Frequencies of 0–10 Mile Visibilities by Wind Directions Observed with 1–10 Mile/Hour Speeds—May, July, September, and November[a]

ESE-W		WNW-E		NW-ESE	SE-WNW
(Urban)	(Rural)	(Urban)	(Rural)		
33.7	26.3	47.2	31.4		

[a] For years indicated in Table IV footnotes.

Table VI—Schematic Shift with Time (Based on Least-Squares Linear Trend Lines) of Los Angeles Visibility from One Range to Another in Percent Frequency

Visibility Range, Miles	Frequency, % 1932	1947	Net Change, % 1932 to 1947		Resultant Shift, % Between Visibility Ranges
		Yearly, 1200 PST, 1932–47			
>35	16.1	0.8	−15.3	+	0 = −15.3
13–35	18.7	17.6	− 1.1	+	−15.3 = −16.4
7–13	20.1	23.4	+ 3.3	+	−16.4 = −13.1
3– 6	29.8	29.4	− 0.4	+	−13.1 = −13.5
0– 2½	15.3	28.8	+13.5	+	−13.5 = 0
		Yearly, 1200 PST, 1948–59			
>35	4.5	4.3	− 0.2	+	0 = − 0.2
13–35	17.2	17.3	+ 0.1	+	+ 0.2 = − 0.1
7–13	22.1	20.3	− 1.8	+	− 0.1 = − 1.9
3– 6	32.0	34.9	+ 2.9	+	− 1.9 = 0 − 1.0
0– 2½	24.2	23.2	− 1.0	+	0 = − 1.0
		Yearly, 1700 PST, 1932–47			
>35	30.4	0.4	−30.0	+	0 = −30.0
13–35	27.9	38.7	+10.8	+	−30.0 = −19.2
7–13	20.9	33.2	+12.3	+	−19.2 = − 6.9
3– 6	16.3	20.8	+ 4.5	+	− 6.9 = − 2.4
0– 2½	4.5	6.9	+ 2.4	+	− 2.4 = 0
		Yearly, 1700 PST, 1948–59			
>35	8.7	8.7	0.0	+	0 = 0.0
13–35	39.9	33.5	− 6.4	+	0 = − 6.4
7–13	27.0	39.0	+12.0	+	− 6.4 = 0 − 5.6
3– 6	18.0	14.5	− 3.5	+	− 2.1 = − 5.6
0– 2½	6.4	4.3	− 2.1	+	0 = − 2.1

58.3 percent at 1200 PST and 58.5 percent at 1700 PST.

For the later period, 1948–59, the resultant percentage shifts between visibility ranges are small and there are some shifts upward to higher visibilities. However, the differences between the resultant upward and downward shifts are relatively slight, indicating very little trend. For instance, at 1200 PST the total resultant shift downward between ranges is 2.2 percent and the total upward shift is 1.0 percent, a difference of 1.2 percent downward. At 1700 PST the total resultant downward shift is 6.4 percent and the total upward shift is 7.7 percent, the difference being 1.3 percent shifted upward.

From a consideration of resultant frequency shifts between visibility ranges it is concluded that at downtown Los Angeles during 1932–47 there was a trend of declining visibility, and during 1948–59 there was practically no trend. While it is not the purpose of this paper to discuss the effectiveness of control programs, it should be mentioned that throughout the periods studied, and in particular with respect to 1948–59, the population of Los Angeles was increasing rapidly. In addition to the 1200 and 1700 PST yearly data of Table VI the data were also considered by seasons, as in Neiburger's report. These results are in general agreement with those of Table VI, although visibility characteristics vary somewhat by seasons and time of day. Analysis of 0500 PST data, which only extend from 1932 through about 1948, clearly indicated a declining visibility trend.

The method of trend analysis that was applied to Los Angeles data is precisely the same as that developed for the Central Valley. In the Los Angeles data used here visibility observations during precipitation were excluded. Although observations with humidities greater than 90% were not deleted, their effect is considered negligible, especially at 1200 and 1700 PST. For the period covered by his study Neiburger has concluded that the changes in visibility at Los Angeles are not due to changes in weather conditions.

Conclusions

A method of analysis has been introduced for the treatment of visibility trends. This method is based on the assumption that with a trend of deteriorating visibility, the resultant changes (with time) in the percent frequencies of visibilities in given ranges shift downward to each next lower range of visibility.

Data for Bakersfield and Sacramento indicate a trend of deteriorating visibility. At both airport sites poor visibilities are shown to be more frequent with air flow from nearby urban complexes than from rural areas. This relationship, together with a rapidly expanding population, is further evidence for a trend of declining visibility throughout the Central Valley. In addition to pollution from population centers there are other sources whose effects on visibility are more difficult to analyze; for instance, open burning practices, particularly with respect to agricultural waste elimination, range land clearance, and uncontrolled fires.

A relationship between wind speed and visibility indicates that with intermediate speeds there is a smaller percent frequency of poor visibilities than with both higher and lower wind speeds. This is interpreted as due to dusts becoming airborne at higher wind speeds, and atmospheric dispersion of pollutants being reduced at lower wind speeds.

Application of the method of trend analysis to Los Angeles visibility summaries indicates a declining visibility trend prior to controls on certain emissions. After such controls the trend is negligible. The significance of the latter trend is that it occurred while the population was growing rapidly.

Acknowledgments

The Bakersfield tabulations were prepared by the U. S. Weather Bureau from punched cards on file at the National Weather Records Center, Asheville, N. C. Machine tabulations of the Sacramento data were prepared by the Tabulation Section of the California State Department of Public Health from original observation records which were kindly made available by the Sacramento U. S. Weather Bureau.

Donald Pack and Robert McCormick of the U. S. Weather Bureau offered helpful suggestions, and Arthur Stern of the U. S. Public Health Service.

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(Continued on p. 449)

A RECOMMENDED METHOD *for* SOILING INDEX SURVEYS *by* AUTOMATIC *Filter Paper* SAMPLER*

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The fine, suspended solids that pollute the outdoor air have a great influence upon community life and thus are recognized as a major air pollution problem. Fine particle air pollution, as distinguished from the larger, fast-settling solids measured by dust fall methods, is produced by a multiple of sources, some natural, others man-made. Among those of natural origin are wind-blown earth and rock dusts, plant pollens, and crystalline substances from salt-water sprays. Man-made sources are equally diversified including smoke particle emissions from domestic, commercial, and industrial heating plants, particulates from automotive engine exhaust, road dusts and industrial processes discharging dusts and fumes to the atmosphere.

Consider the multiformity of airborne particulates; combine this with such influencing factors as weather and topography, and the problem becomes one of complexity. No one sampling method or technique will provide all of the answers related to the types, quantities, and effects of fine particle air pollution. Each community or research agency must therefore choose a technique or series of techniques that will best satisfy its own individual needs and budget limitations.

In industrialized communities and in colder climate areas where heating demands result in mass smoke particle emissions, one of the major adverse effects of fine particle air pollution is the soiling of surfaces, both interior and exterior. The exterior surfaces of buildings and other objects exposed to the outdoor air are noticeably affected in these communities and areas. The same dirt-laden air penetrates into the home and other buildings, further adding to the soiling of home furnishings, walls, and other surfaces.

The Measurements Committee of the Air Pollution Control Association, in their forthcoming standard method manual (APM-2), are including a recommended standard method for evaluating soiling properties of the air. The Committee's purpose in selecting a standard method is to provide various communities with a means of gaging the soiling properties of their respective atmospheres. By using a comparable method, one community could, after a period of sampling long enough to determine the diurnal and seasonal variations, compare their own soiling index with that of other communities of similar character.

The Bureau of Air Pollution Control and Heating Inspection, City of Cincinnati, was asked to submit to the APCA Measurements Committee, a recommended method for continuing soiling index surveys by automatic filter paper sampler. Using the knowledge gained from seven years of continuous soiling index sampling in Cincinnati, the authors have formulated the following method and are submitting it to the committee for their consideration.

Before proceeding to the method outline, brief comment is made on some of the factors that led to the selection of this particular method.

Prime considerations in selecting the monitoring procedures for community air pollution control programs are those of cost, time, and required technical skill. Unfortunately, today many air pollution control agencies must operate within the boundaries of a small budget and consequently the air monitoring activities are grossly inadequate. The objective is to get the most valuable information attainable from the limited funds available for this purpose.

Representativeness and accuracy are also major considerations in selecting any such method. Certainly the optical density of soiled spots on filter paper will not, in itself, indicate the size, weight, and size-frequency distribution of fine particulates in the air sampled. It will, however, provide a general index of the levels and trends of the soiling properties of the air in relation to light-surface objects. It will also show periods of maximal and minimal pollution from many other contaminants, particularly those associated with combustion processes. Thus more effective time scheduling of companion sampling programs is attained. This method is therefore directed toward the measurement of the soiling index, and any further refinements or other applications are left to the investigator.

Regarding the accuracy requirements for soiling index measurements, there are a number of errors inherent in the sampling and quantitating of data obtained by such a method. Application of correction factors for some of the variables that affect the results may be applied with relative ease. Corrections for all variables, however, will require considerably more time and materially add to the cost.

The question that now arises is: How shall we measure soiling index? With a micrometer or a six-foot rule? The authors have chosen the latter. This is not to say that the instrument and method variables have been overlooked. Each of the variables encountered in the investigative work that led to the writing of this procedure were considered. Some are stipulated in the procedure, others are merely mentioned and left to the prerogative of the investigator.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

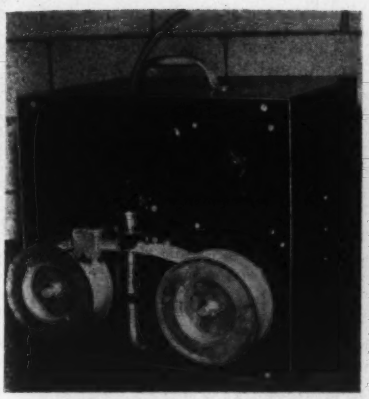

Fig. 1. AISI automatic air sampler, Model E.

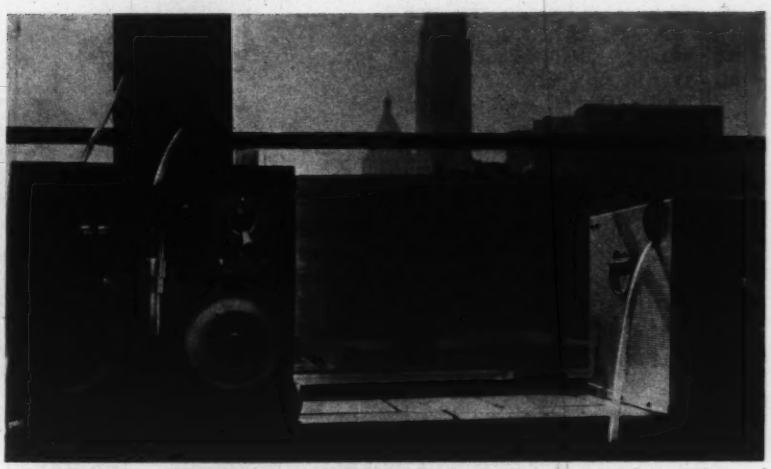

Fig. 2. Downtown sampling station, Cincinnati, Ohio. Outdoor air being sampled from penthouse of Public Library by means of a three-foot length of tygon tubing.

Recommended Method for Survey by Automatic Filter Paper Sampler

As stated in the introduction, it has been deemed desirable to select one method for presentation. It is also considered desirable to select one instrument from among several available, and write a standard method for a continuing survey around this particular instrument. At the time of this writing the most widely used instrument is the AISI Automatic Air Sampler and, therefore, the procedure is written around this unit. Other instruments of a similar type can be readily adapted to the method by considering their individual characteristics and applying the appropriate factor.

Instrument Description

The AISI Automatic Air Sampler (Fig. 1) is a self-contained unit incorporating a diaphragm type reciprocating pump, a supply and collecting reel of Whatman No. 4 filter paper, and a timing and indexing mechanism. The 15 rpm pump pulls approximately 0.25 cfm of air through a one-in. diameter area of the filter paper, thereby leaving a spot on the paper one in. in diameter. At the end of the sampling period (pre-selected from two minutes to three hours) the tape automatically indexes and the new sampling cycle begins.

At a convenient interval, usually one week, the spots are removed and evaluated. Evaluation is by the use of instrumentation measuring the reflected light from the test spot or the transmitted light through the spots. The result is referred to as the "soiling index." The instrument is now available with either an automatic or manual spot evaluator.

Planning the Survey

The number of sampling sites will depend upon the complexity of the area to be surveyed and the resources available for conducting the survey.

Classification of the Area[1]

The area served by each sampler will be classified according to the character of urban activity in the vicinity of the station. The type of activity within one quarter mile of the station will determine the primary classification. A secondary classification will be determined by the type of activity within one-half mile from the station. Classification shall always be reported by primary and secondary classification, such as Zone AA or AF. Note should be made of any major source or sources of smoke or other visible emissions within one mile of the station. Area classifications are shown as follows:

Zone A—Residential, low density (10 dwelling units or less per acre and nonrural)
Zone B—Residential, high density (more than 10 dwelling units per acre)
Zone C—Commercial, neighborhood shopping district
Zone D—Commercial, central business district
Zone E—Industrial, with low air pollution potential
Zone F—Industrial, with air pollution potential
Zone G—Rural, one dwelling unit per five acres or larger area.

Selection of the Site for the Sampling Station

The sampling station must have a rather free exposure. However, the presence of obstructions such as buildings, tanks, etc., are not as important as for dust fall measurement (reference APM-1). Strictly local sources of fine particles, particularly the plume from a potentially smoking chimney, should be avoided.

The height above grade is important where temperature inversions are frequent. The height should not be greater than 100 ft nor lower than 15 ft above the grade or street level. If the height of the station is outside of the foregoing values, appropriate note should be made. Concurrent sampling at two downtown locations in Cincinnati, one at an elevation of 85 ft above grade, the other at 580 ft above grade, revealed a high degree of uniformity during periods of good atmospheric mixing. However, during periods of inversions and low wind movement, wide variation appeared between the two elevations.[2]

Public buildings such as schools, fire stations, libraries, etc., are most favorable to public agencies because of their accessibility and security. However, the AISI Sampler can be operated in a private residence without undue disturbance to the occupants if reasonable care is taken in the placement and noise shielding of the instrument during set-up of the operation.

Spacing Between Stations

The spacing between stations will depend upon the character of the area to be surveyed, the meteorology, the topography, and the distribution of air pollution sources. There is a considerable uniformity of distribution of particulate matter in the size range being considered, so that a single sampling instrument will represent a considerable area of uniform character and topography.

Control Station

For a continuous survey, one or more control stations are recommended. A control station will be located in a Class G (rural) area sufficiently removed from local influences so that it will measure the natural characteristics of the geographical area which would be under study.

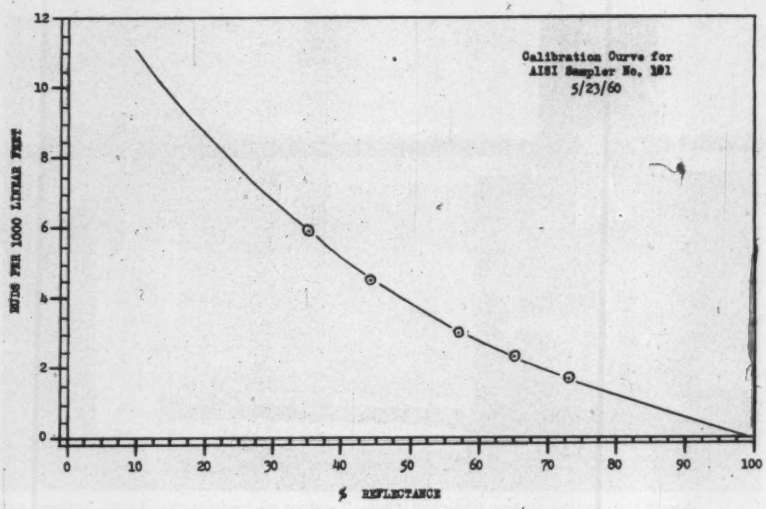

Fig. 3.

Table I—Calibration Data for AISI Sampler #101

% Reflectance of Standard Spot	Measured Flow, Cfm (V)	Average Flow, Cfm (V_{avg})[a]	Optical Density[b]	RUDS/1000, L.F.[c]
100	0.260	0.260	—	0
73	0.247	0.253	0.137	1.6
65	0.235	0.247	0.188	2.3
57	0.229	0.245	0.243	3.0
44	0.216	0.238	0.356	4.5
35	0.208	0.234	0.456	5.9

[a] Average Flow $= \frac{\text{Flow Clean} + \text{Flow Dirty}}{2}$.

[b] O.D. $= \log_{10} \frac{\%\text{ Reflectance Clean}}{\%\text{ Reflectance Dirty}}$.

[c] RUDS/1000 L.F. $= \frac{\text{O.D.} \times 10^5}{L}$.

For 1 in. diameter spots and 3-hr samples, $L = \frac{(180\text{ min})\,(V_{avg})}{0.0054\text{ sq ft}}$.

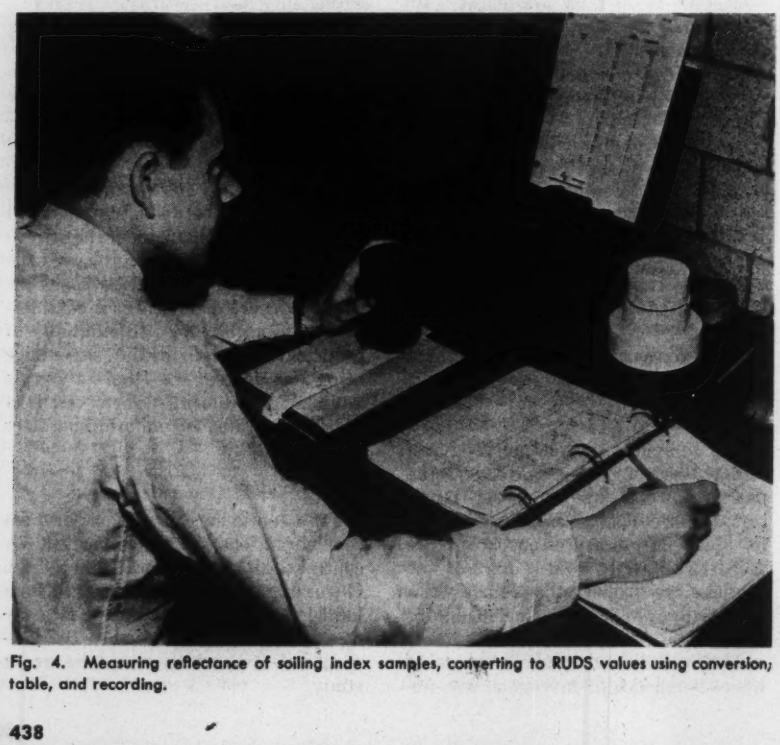

Fig. 4. Measuring reflectance of soiling index samples, converting to RUDS values using conversion table, and recording.

Maintenance of the Site

Once selected, a site should be maintained unless conditions occur to cause undue unfluence on the sample or to create an unsatisfactory condition.

Length of Sampling Period

The length of the sampling period need not be fixed. It should be sufficiently short so that the optical density of the spot is less than 0.3 (over 50% reflectance or transmission). A three-hour period is lengthened or shortened depending upon the degree of staining to be expected. For a reduction of data the shorter periods are usually grouped into six-hour periods from which the daily, weekly, and monthly averages are determined. The six-hour period will show the diurnal pattern of air pollution build-up and carry away.

Conducting the Survey

The only need for visiting the sampling station is to collect the samples and give the instrument a visual check. Periodical calibration of the instrument is necessary. The length of time between calibrations will depend upon the age and condition of the instruments. Calibration should be done a minimum of once every six months.

Samples are collected once each week. However, there is no deterioration of the sample by allowing it to remain on the instrument for a longer period, so that sample collection could be reduced to once a month. This is not recommended, however, since the weekly visit for inspection of the station and visual check of the instrument is important. Care should be taken in transportation of the samples to avoid soiling. Suitable containers or wrapping for the strip should be furnished for protection from the field to the laboratory or evaluation room.

Evaluation and Interpretation of Data

The two most common methods of evaluating spot samples are based upon the reduction of reflected or transmitted light. These reductions are referred to as optical densities: O.D. = $\log_{10} I_0/I$, where I_0 is the 100% reflectance or transmission of clean paper and I is equal to the measured reflectance or transmission for a specific spot. Therefore, O.D. may be defined as $\log_{10} 100/[\%R \text{ (or } \%T)]$.

Since O.D. determinations do not account for such variables as sampling time, air flow rate, and spot size, comparison of results between sampling stations cannot be made on this basis alone. It therefore becomes necessary to adopt a unit value which will account for such variables. Either of the following unit scales may be employed, depending upon the method chosen for

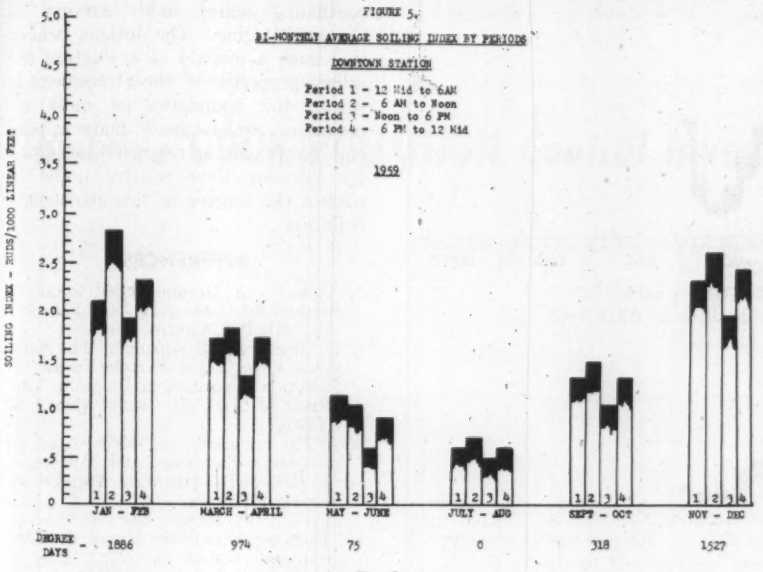

Fig. 5.

determining optical densities, i.e., by light reflectance or light transmission.

Ruds (Reflectance Units of Dirt Shade) Units

When reflected light is used to measure the optical density, the spot values are quantitated by conversion to the RUDS scale. The RUDS unit is obtained by multiplying the optical density by a factor of 100 and the soiling index levels are then expressed as RUDS per 1000 linear feet of air drawn through the filter paper (spot) according to the following equation:

$$\text{RUDS/1000 L.F.} = \frac{\text{O.D.} \times 100}{L} \times 1000$$

$$= \frac{(\text{O.D.})\ (10^5)}{L}$$

Where L is the total cubic feet of air passed through the spot divided by the area of the spot in square feet.

COH (Coefficient of Haze) Units

The COH unit is basically the same as the RUDS unit except that the optical density is determined by transmitted rather than by reflected light. Soiling Index values are expressed in COHS per 1000 linear feet of air according to the same equation used for RUDS.

Quantitating Data

Regardless of the method selected, there are certain inherent variables which should be brought to the attention of the investigator. For example, variations in air flow up to 17.5% and range of transmission readings of 14% have been observed in measurements through blank (clean) fibrous filter paper rolls. These variations may be attributed to differences in fiber diameters and fiber densities (number of fibers per unit volume) within segments of individual rolls.

Other factors to be considered are the differences in air flow rates between samplers and the fall-off in air flow as the instrument diaphragm pump wears with use. The build-up of particulate matter on the filter paper also results in a reduction of air flow as the spots are being collected.

Obviously, there exists a need for calibrating each individual sampling unit and applying appropriate correction factors to minimize the effects of these variables in the resulting data. Several methods have been suggested.[3–5] Although the technique suggested in the method outlined below may differ somewhat from the methods referred to, there is no substantial disagreement. Again, it is pointed out that this method is aimed at gaging, with reasonable accuracy, the soiling properties of the atmosphere as they affect light-surface objects, and any further refinement of the method for other applications is left to the prerogative of the investigator.

Method Calibration Procedure

The following procedure is based upon the RUDS (reflectance) method. The same procedure may be used for the COH (transmission) method by merely substituting the word COH for RUDS and % transmission for % reflectance.

Since three-hour sampling periods are recommended, the linear feet values are calculated on a 180-min basis. An example of a typical calibration procedure is shown in Table I and Fig. 3.

1 A series of spots ranging in reflectance from 35% to 100% is selected from true samples collected from the outdoor atmosphere in the area being studied. It is preferable to use three or more samples of the same reflectance so that a better average may be obtained in the subsequent results.

2 Using a dry test meter, or other air flow calibration instrument, the air flow (V) through each of the standard spots is measured. A minimum flow of two cubic feet of air should be allowed to pass through each spot.

3 The average air flow through each spot (V_{avg}) is computed. If more than one standard is used, use the average of the set of equal reflectance values

$$V_{avg} = \frac{\text{Flow Clean} + \text{Flow Dirty}}{2}$$

4 The optical density of each of the standards is calculated and converted to RUDS/1000 linear feet according to the previously illustrated equation [See under "Ruds (Reflectance Units of Dirt Shade) Units"].

5 These values are then plotted versus their corresponding reflectance values and the calibration curve drawn.

6 Using the calibration curve (Fig. 3) a conversion table of reflectance readings versus RUDS/1000 L.F. (Table II) is made.

7 As the spots are read, their reflectance readings can then be immediately converted to soiling index expressed as RUDS/1000 L.F., and so recorded (Fig. 4). (*Note:* If the reflectance method is used, it is suggested that a green filter (of the set of tristimulus filters) be inserted into the photocell unit. By this means the spots are graded through a series of achromatic colors (grays, ranging from white to black) and the "lightness" or "darkness" of the spots are determined without regard to the hue of the particles.)

Reduction and Reporting of Data

A pattern of the diurnal, monthly, and seasonal trends may be obtained by grouping sample results into six-hour periods beginning at 12 o'clock midnight. An example of this type of grouping is given in Fig. 5, a bi-monthly summary of soiling indices by six-hour periods. Year-to-year trends may be graphically shown as in Fig. 6, also using bi-monthly intervals. Weekly, monthly, and yearly averages may be obtained using the six-hour averages.

Companion meteorological data recorded with soiling index values should include: 1) wind velocities and direction, 2) precipitation, 3) ambient air temperatures, 4) humidity, and 5) observed visibility from the sampling station.

Summary and Conclusion

This recommended method for fine particle measurement by the AISI sampler is based largely upon the knowledge gained from seven years of

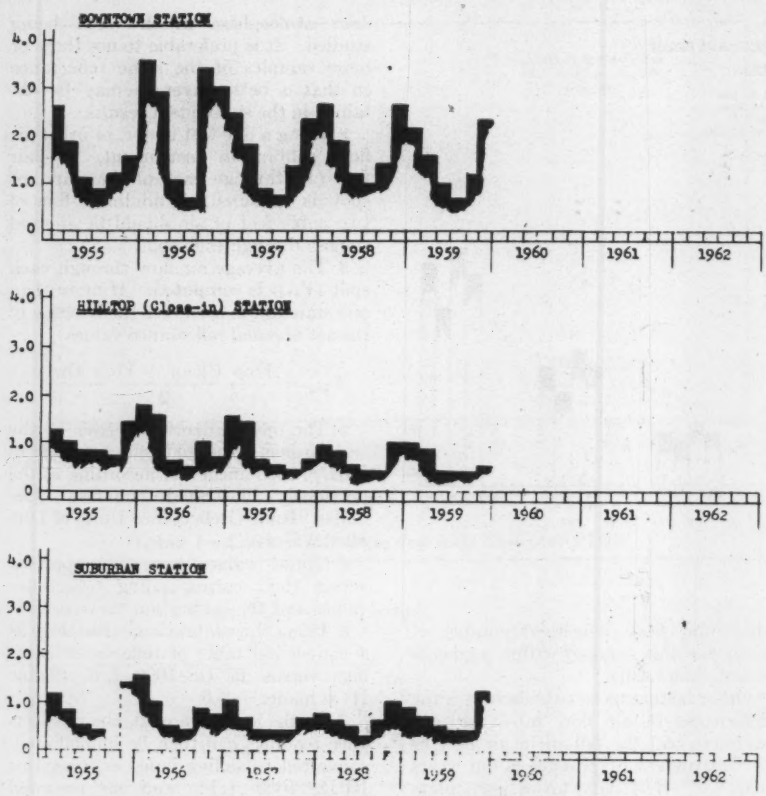

Fig. 6. Average bi-monthly soiling indices since 1955 (RUDS per linear feet).

Table II—Conversion Table for AISI Automatic Sampler Results

Percent Reflectance to RUDS per 1000 Linear Feet

Calibration Date: May 23, 1960 Sampler No.: APC 101

% Reflectance	RUDS Per 1000 L.F.	% Reflectance	RUDS Per 1000 L.F.	% Reflectance	RUDS Per 1000 L.F.
10	11.1	40	5.1	70	1.9
11	10.8	41	4.9	71	1.8
12	10.6	42	4.8	72	1.7
13	10.3	43	4.7	73	1.6
14	10.1	44	4.5	74	1.6
15	9.9	45	4.4	75	1.5
16	9.6	46	4.3	76	1.5
17	9.4	47	4.1	77	1.4
18	9.2	48	4.0	78	1.3
19	9.0	49	3.9	79	1.3
20	8.8	50	3.8	80	1.2
21	8.5	51	3.6	81	1.2
22	8.3	52	3.5	82	1.1
23	8.1	53	3.4	83	1.0
24	7.9	54	3.3	84	1.0
25	7.7	55	3.2	85	0.9
26	7.5	56	3.1	86	0.9
27	7.3	57	3.0	87	0.8
28	7.1	58	2.9	88	0.7
29	6.9	59	2.8	89	0.6
30	6.8	60	2.7	90	0.6
31	6.6	61	2.6	91	0.5
32	6.4	62	2.5	92	0.5
33	6.2	63	2.4	93	0.4
34	6.1	64	2.3	94	0.3
35	6.0	65	2.3	95	0.3
36	5.9	66	2.2	96	0.2
37	5.7	67	2.1	97	0.2
38	5.4	68	2.0	98	0.1
39	5.2	69	1.9	99	0.1

continuing soiling index surveys in Cincinnati, Ohio. The authors believe that such a method of evaluating the soiling properties of the atmosphere is within the boundaries of most air pollution control agency budgets, and will provide data of reasonable accuracy for assessing their relative needs to control the sources of fine particulate pollution.

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SUBSIDIARY COMPANY FORMED BY UNIVERSAL

Universal Oil Products Company, Des Plaines, Illinois, has formed a subsidiary with offices here to establish operations for marketing Purzaust, UOP's catalytic muffler to aid in smog-control.

Office of the subsidiary, Universal Oxidation Processes, Inc., is at 811 West Seventh St. Universal Oxidation will "handle the manufacturing and marketing of Purzaust upon its certification by the state Motor Vehicle Pollution Control Board," M. P. Venema, president of the parent company said.

Purzaust Only One Device

Purzaust is one of a number of devices under study by the California Board as a means to aid in the reduction of smog in the Los Angeles area. Motor vehicles will be required to use a device to remove unburned hydrocarbons and carbon monoxide from exhaust gases after at least two devices are certified by the MVPC Board. Automotive exhaust is believed to be a major cause of smog.

Purzaust is designed for installation on new vehicles or as a replacement of standard mufflers on older ones, Mr. Venema said. It contains a catalyst for converting smog-causing components in exhaust gases into nonirritating compounds. Close to a half million miles of road testing by UOP shows that Purzaust will assure satisfactory performance over extended periods.

Objective ODOR POLLUTION Control Investigations*

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The tremendous growth of industry in recent years has been responsible for much of the progress and prosperity now enjoyed in the United States. However, with this growth, there also came new sources and new aspects of air pollution. The aspect which will be considered is that concerning investigation of odors associated with various manufacturing processes.

Investigation of odor complaints by air pollution control personnel have followed a rather well-defined procedure. The investigation is initiated by a telephone call from an irate citizen. The description of the odor situation is reduced in writing and given to the inspector who proceeds to the troubled area equipped with two things, his endowed sensory perception and, at times, a prior knowledge of potential odor sources in the affected area.

Arriving at the scene of the complaint, the inspector will mentally form an impression of the severity of the odor situation expressed as weak, moderate, or strong. The inspector can make an estimate of the wind direction from a visible plume in the vicinity and coupling with this his knowledge of odors associated with various manufacturing processes, he can form a general opinion of the direction and type of source. If he is familiar with the area he may recognize the true offending operation. However, if the odor has dissipated or if a long time has lapsed between the complaint and the investigation, then an on-the-spot trace to the odor source cannot be made.

In many cases the odor situation has changed from the time of the complaint so that a personal interview with the complainant is necessary. During the interview a description of the odor situation is influenced materially by the emotional stability of the complainant. In such investigations, the position of the inspector is that of an arbitrator between management and citizens. This position must be changed to one of a true enforcement officer through more adequate methods of investigation.

The objective of any odor investigation is to obtain elimination or correction of the source. This can be accomplished either through voluntary action by plant management (a much preferred procedure) or through legal action.

If the former course of action develops, certain stumbling blocks may arise to deter the correction process. Local management may have a very co-operative attitude, but the cost of control equipment may be prohibitive. Often, between citizens and plant management, there is a wide difference of opinion as to the seriousness of the odor situation, and therefore, the need for corrective measures. At times, because of the lack of positive identification, errors in odor descriptions, or a lack of accurate localized meteorological information, doubt may arise as to the suspected source and positive proof will be demanded by the suspected plant manager. This would be particularly true in complex situations where many sources are located within the same area and the cost of correction is high.

The latter course of action, that is, legal procedures, may become necessary because of a gross disregard for community relations by the source management or it may be dictated by the economic situation. The cost of correction may not be economically feasible and a court decision is sought to establish in fact that a violation of the air pollution ordinance has occurred and that corrective measures are a legal necessity. In such cases the court decision may fix the extent of correction.

The language of air pollution ordinances dealing with odor nuisances is broad and subjective. Only in recent years has attention been given to an objective criteria for outdoor odor situations. However, to date, no community has yet written objective odor criteria into their Air Pollution Control Ordinance. Therefore, legal procedures are used to settle unresolved differences of opinion between citizen and source management and to establish whether or not a violation exists.

To those engaged in air pollution control work either for the government or industry it is readily apparent that more objective odor complaint investigative procedures must be developed. To accomplish this a device or instrument for the determination of odor strength is of prime importance. Techniques to point out the offender from among a number of potential sources are also needed. With the development of objective procedures and the enactment of reasonable ordinances containing measurable odor characteristics, the effort expended in odor pollution correction will be more beneficial to the community.

The Nature of Ambient Odors

For the purpose of air pollution control, odors are classified in two categories, ambient and source odors. Ambient odors are those existing in the general atmosphere and source odors are defined as those at the point of origin or at their point of exit to the general atmosphere. If odors occurred only at their source and were immediately dissipated there would be no air pollution problem. However, this situation does not prevail and the ambient odor problem arises. The specific ambient odor characteristics of concern to the air pollution control personnel are quality, strength, and occurrence.

Quality of odor as yet is described in subjective terms such as a degree of pleasantness or by comparison with a similar known odorant such as rotten

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Fig. 1. The Scentometer Model 1959A.

eggs, peppermint, etc. From the standpoint of the air pollution officer quality is a very complex issue and cannot be described in objective terms. For the present it must remain in ordinances as broad word definitions.[1]

Odor strength can be expressed objectively in terms of the amount of air needed to dilute the given amount of odorous air to the concentration at which the odor is just detectable by the human olfactory system. Strength has been expressed in terms of odor units,[2, 3] an odor unit being defined as 1 ft^3 of air at the odor threshold. Other units of odor strength are the threshold concentrations and multiples thereof. The latter term is unitless and, therefore, has certain advantages. For example: an odor having a strength of 10 odor units/ft^3 is equivalent to a strength of 10 times the threshold concentration or 10 dilutions to the threshold concentration (abbreviated—10 D/T).

In discussing the strength of ambient odors, it is well to look deeper into their nature. Through repeated association of the word ambient with odor, the true meaning of ambient is usually overlooked. Ambient odors are thought of as those occurring out-of-doors; however, the true meaning of the word ambient as expressed by Webster is "moving around" or "encompassing on all sides." The first definition should lead us to realize that the strength of an ambient odor is changing constantly with each air movement. Therefore, strength of an ambient odor loses meaning unless it is accepted as the maximum strength found.

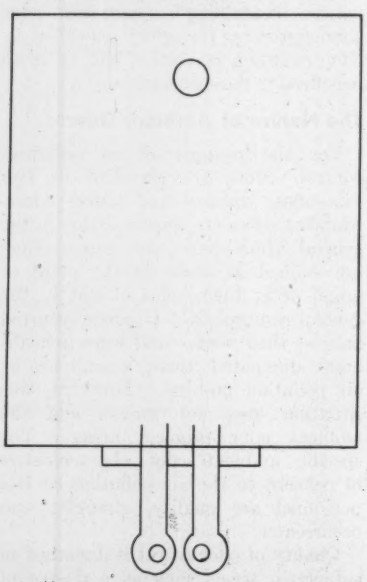

Fig. 2. Diagram of the top or the bottom section, showing the purified air inlet.

Occurrence, for purposes here, will be defined in terms of duration and frequency. It is often found that the interval of duration of an ambient odor is brief, for example two or three min, and that the frequency is several times per hour. This points out the need for an expression of the interval of time during which the sporadic durations occur. Therefore, occurrence should be expressed as having occurred at intervals (giving average length of time) with a given frequency during a known period of time.

In summation:

1 Quality is a subjective characteristic which is best discussed only in general descriptive terms.

2 Ambient odor strength should be accepted as the maximum strength found. The unit of expression most suitable for this work is the number of times that the odor is as strong as its threshold concentration or the number of dilutions with pure air needed to dilute it to the threshold concentration. This expression can be written as D/T (dilution to threshold).

3 Ambient odor occurrence includes the average length of time at which intervals occurred. Frequency during a known period of these occurrences, and the total length of time during which the odor nuisance was present.

Measurements of Odor Strength—the Scentometer

Measurement of the strength of ambient odors in the past has not been practical due to the lack of a reliable measuring device. After investigation of various instruments which might have been capable of measuring ambient odor strengths and finding all to be lacking for this purpose, a new instrument, called the "Scentometer," was designed. The Scentometer is an organoleptic instrument of the vapor dilution type. The various dilutions are supplied by combinations of critical size orifices. Purified air for the purpose of dilution is supplied from activated carbon beds. The mixture is delivered to the olfactory tract for appraisal through two nose pieces, air being drawn through the instrument by the action of the observer's lungs. Figures 1, 2, 3, and 4 show the Scentometer and its general arrangement. Figure 5 is a list of the component parts needed to build such an instrument. The parts are welded together by using a mixture of dichloroethylene and plexiglas.

Table I—Scentometer Dilutions

Odorous Orifice, Diam Size, In.	No. of Dilutions to Threshold, D/T
1/2	2
1/4	7
1/8	31
1/16	170

The current model Scentometer is capable of four different dilutions and thus divides odors by strength into five groups. Experience has shown that odors above 7 D/T will probably cause complaints while those above 31 D/T can be described as a serious nuisance if they persist for any length of time. (Table I.)

The orifice sizes to accomplish these dilutions are: purified air inlets of 1/2 in. diam, leading to the carbon beds, and odorous air inlets of 1/2, 1/4, 1/8, and 1/16 in. diam leading directly to the mixing chamber. The purified air inlets are located in the top and bottom sections of the Scentometer (Fig. 2) and are separated from the filter beds by a plenum chamber. The odorous air inlets are located on the front side (opposite the nose pieces) of the Scentometer as shown in Fig. 4. These are opened and closed by means of tape tabs.

The size of the Scentometer body is 5 in. x 6 in. x 2.5 in. Figure 3 is a cross section through the body. Seven distinct layers are apparent. They are, starting from the top: 1/4 plexiglas wall, plenum chamber for air which will be purified, activated carbon filter, air chamber where odorous and odorless air is mixed for delivery to nose pieces, activated carbon filter, plenum chamber for air which will be purified, and 1/4 in. plexiglas wall.

The activated carbon which has been used in the filter beds is that which is obtained from coconut shells. The life of this carbon depends upon the frequency of use. From experience we have found that these filters are serviceable for at least three months, when used on daily odor patrols. Repacking of the filters with new carbon when necessary will not change the dilutions to any appreciable amount. This has been proved by air flow measurements.

Measurement of ambient odor strength is not a simple matter, however the difficulty does not lie in the instrument, rather it is inherent in the variability of the ambient odors. Some odors occur in narrow streams which move about rapidly, some are very intermittent. To cope with these

variations, different methods of using the Scentometer have been developed.

In the normal method of use, the Scentometer is breathed through for a minute with all odorous air inlets closed. This period of time is to refresh or defatigue the observer. Then the small odorous orifice which gives the highest dilution is opened and if no stimulus is obtained the next larger orifice is tried until a positive stimulus is obtained. The strength of the odor is designated as the dilution which first gives the stimulus.

In cases where the narrow odor streams occur, it is advisable to use a different procedure. Move through the odorous area either in an automobile or on foot while breathing through the scentometer set to obtain the highest dilution. If no stimulus is obtained, travel back through the area using successively the next lower dilution until an odor stimulus is obtained.

In cases when the odor is very intermittent, breathe through the Scentometer for a minute with all odorous air inlets closed. Remaining stationary, open the highest dilution orifice and continue breathing through the Scentometer for about 5 min. If no stimulus is obtained during this period of time, proceed successively through the lower dilutions until a stimulus is perceived.

Accuracy and precision of results depend upon the human olfactory sense, since the Scentometer is an organoleptic measuring device. It has often been said but never shown that the olfactory sense is subject to variations from person to person and/or from hour to hour in the same person. Accuracy and precision of results have always been improved by increasing the number of observers. The use of a panel of observers is impractical for day to day air pollution control work. Therefore, to determine the necessity of panel observations, the limitations of the olfactory sense were investigated.[4] Investigations were conducted using successively stronger liquid dilution sniff bottle samples.

These tests were done to determine specifically the day to day variation in the olfactory ability. Two persons were given the same liquid dilution series on ten different days, both subjects were influenced by head colds of varying degrees. Results of these tests are shown in Table II.

The variation in olfactory ability between different individuals was investigated by giving five different tests (odorants) to 17 different observers. These results are shown in Table III.

In these tests there was no screening of observers. Observers were accepted with or without head colds of any degree. As long as it is understood that these variations and results can

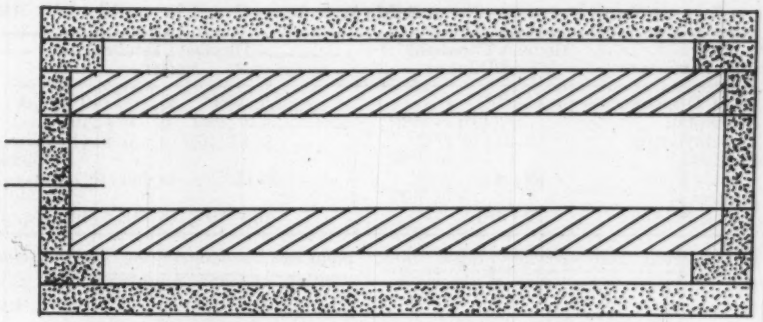

Fig. 3. Cross section, showing the positions of carbon filters and the nose pieces.

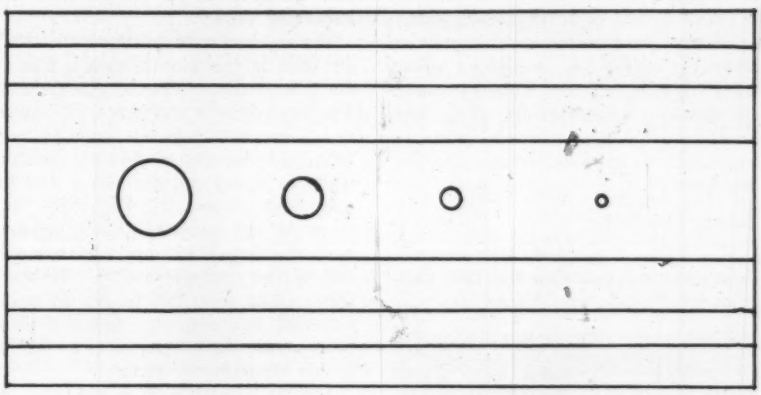

Fig. 4. Diagram of the frontpiece showing the positions of the odorous air inlets.

Material	No. of Pieces	Size (in In.) Length	Width	Thickness
Plexiglas	2	6.0	5.0	0.25
"	8	5.0	0.5	0.25
"	4	5.5	0.375	0.25
"	4	5.0	0.375	0.25
"	2	5.5	0.75	0.25
"	2	5.0	0.75	0.25
Brass Screen	4	6.0	5.0	—
Solution	Containing 256 holes (approximately 1 mm) per sq in. of Plexiglas in Ethylene Dichloride (30% by vol) approximately 50 ml needed			
Activated Carbon	Approximately 6 oz/Scentometer Barneby-Cheney Co. A-C 4			
Glass Tubing	Length 12 in. and diam 10 m			
Plastic Tape	2 ft			

Fig. 5. Scentometer parts list.

Table II

Observer	Medium Threshold Liquid Dilution	Threshold Range
1	7.5 (10^4)	4.3 (10^4) to 13.0 (10^4)
2	2.9 (10^4)	1.3 (10^4) to 6.4 (10^4)

Table III

Test Odorant	Medium Threshold Liquid Dilution	Threshold Range
Oil of Turpentine	24 (10^2)	4 (10^2) to 106 (10^2)
Mercaptan	2.4 (10^4)	0.8 (10^4) to 6.4 (10^4)
Dimethylamine	0.39 (10^8)	0.13 (10^8) to 2.0 (10^8)
Synthetic Body Odor[a]	76.8 (10^3)	25.6 (10^3) to 205 (10^3)
Synthetic Hospital Odor[a]	23.4 (10^8)	6.4 (10^8) to 85 (10^8)

[a] Supplied by Airkem, Inc., New York, N. Y.

Table IV

Test Odorant	Medium Threshold Liquid Dilution	Threshold Dilution Range
Oil of Turpentine	24 (10^3)	8 (10^3) to 64 (10^3)
Mercaptan	2.7 (10^4)	1.1 (10^4) to 6.4 (10^4)
Dimethylamine	0.34 (10^5)	0.13 (10^4) to 0.84 (10^5)
Synthetic Body Odor	68 (10^3)	34 (10^3) to 136 (10^3)
Synthetic Hospital Odor	20 (10^4)	6.4 (10^4) to 51.2 (10^4)

be expected and are acceptable, no panel results nor screening of observers are necessary.

By a 50% screen of observers, results in Table III can be changed to those in Table IV.

These figures show that with some screening of inspectors, variations in olfactory ability is negligible when using the Scentometer. This is because the olfactory variations are within the limits of the measurement intervals incorporated in the design of the Scentometer.

Source Location

The basic fact that odor travels downwind substantiates the fact that wind direction in an odorous area will point out the odor source. In the investigation of odor complaints, to substantiate the accusation of the suspected source and/or to determine an unknown source, accurate wind direction data gathered at the odorous area are important.

The method used to determine wind direction in the odorous area is that of low flying balloons inflated with helium. The procedure is as follows: While in an odorous area inflate a small balloon with sufficient gas so that the balloon will rise slowly, release and watch its path with a compass. Point the "N" mark on the compass at the balloon, read the degree number at the south end of the compass needle. Subtract this reading from 360 to get the wind direction and degrees. Figure 6 is a photograph of the equipment needed to gather wind direction data.

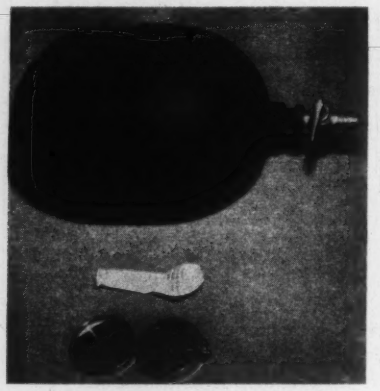

Fig. 6. Equipment for the determination of wind direction.

Figures 7 and 8 give examples of actual cases using data from multiple balloon releases. Figure 7 contains 11 wind directional lines which were obtained during 11 different complaint situations against the same plant. The observation points are shown as dots and the lines from the dots represent the wind direction or the direction from which the odor was coming. The suspected source is shown in black. These 11 determinations give conclusive evidence that the suspected plant is the true source.

Figure 8 is an example of determinations of an unknown source within a multiple source plant. There are approximately 24 individual chemical manufacturing buildings within this one complex company. The three wind directions obtained during three different occurrences have narrowed the field down to four buildings. Independently, the plant personnel then traced the source to the plant noted on the diagram in black, confirming the source identification by the wind triangulation method.

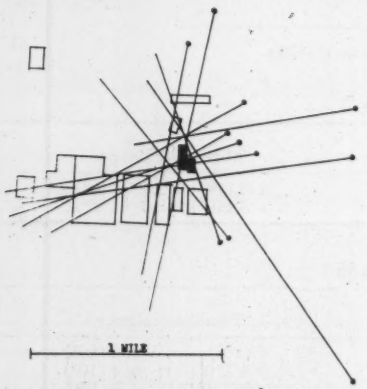

Fig. 7. Verification of a suspected source: The buildings in black are the suspected source, the black dots at the end of the lines represent the observation points, and the lines represent the wind direction at the time of the observation.

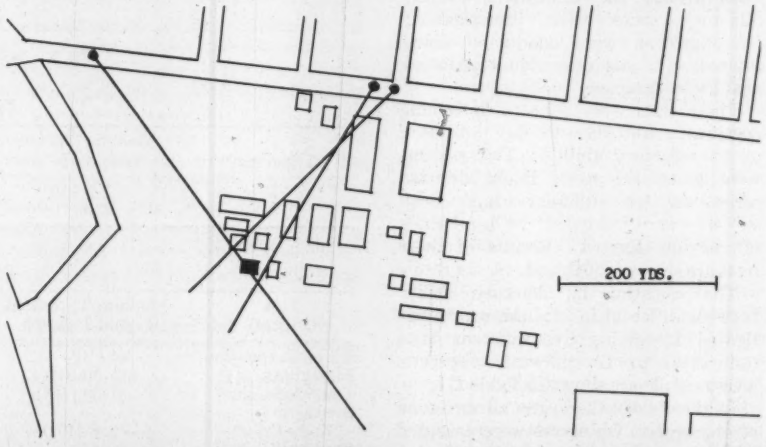

Fig. 8. Detection of an unknown source: The building in black was the unknown source, the black dots at the end of the lines represent the observation points, and the lines represent the wind direction at the time of the observation.

Table V—Effect of Time of Year

Month of Year	Number of Complaints	Number of Nuisance Occurrences
January	..	..
February	..	..
March	1	1
April	6	4
May	9	4
June	14	9
July	28	16
August	44	18
September	34	18
October	2	2
November	1	1
December	..	..

Note: The number of nuisance occurrences refers to the number of different days on which complaints occurred. Note that 86% of the complaints and 84% of the occurrences happened during the months of June, July, August, and September.

Standard Procedure for Ambient Odor Investigation

In summary of the previous discussions, it seems appropriate to suggest that the following considerations on the procedure for the investigation of odor complaints be established:

1 Complaint: Information for the record obtained from the complainant should contain the following information: Name and address of the complainant, time and location of the complaint, a description of the odor (if unable to describe the odor, have the complainant liken it to an odor which he can describe), and finally, the suspected source.

2 Observation: The observation report should include the following detailed information: Location and extent of the odor situation, recorded times of all measurements taken during the investigation, the type of odor, occurrence of the odor in terms of frequency and duration, the source suspected by the inspector, distance and range that the odor situation exists from the suspected source, and the angle formed at the suspected source from north to the location of the odor.

3 Meteorology: Determine the localized wind direction at the site of the ambient odor and record this direction in degrees from north.

4 Plant Interview: Once a determination has been made as to the source of the odor situation, the name of offending source as well as the responsible supervisory employee on duty should be obtained. The interview with the supervisor should reveal how and why the odor situation occurred and the nature of corrective measures which will be taken to abate the odor.

5 Complainant Interview: A report on the odor investigation should then be made to the complainant. At this time it is wise to obtain any additional information from the complainant which would tend to clarify the complaint situation. At a later date, the complainant should be notified as to the progress of action which is being taken on the complaint situation.

Having obtained the information as outlined above, the odor investigator may return to his office and log much of this data on area maps. Assembly of the facts in this manner will show the relationship between the complaint location, location of the observed odor, wind direction and the location of the suspected or unknown source. With this information at hand, the courses of action to obtain correction within the policies and authority of the air pollution control agency are established.

Meteorological Effects on Odor Nuisance Occurrences

Meteorology plays an important part in the build-up of odor nuisance occurrences. In an effort to have a better understanding of the weather both favorable toward and against such occurrences, the following study was made. The meteorology at the time of complaints was collected and grouped to show its effects. All meteorological data were taken from the records of the U. S. Weather Bureau Station which is located some 15 miles from the meat rendering plant against which all of these complaints were filed. (See Tables V through XII.)

In summary, the weather conditions to watch as those most conducive to

Table VI—Effect of the Day of the Week

Day of Week	Number of Complaints	Number of Nuisance Occurrences
Sunday	19	7
Monday	15	11
Tuesday	8	6
Wednesday	10	7
Thursday	17	10
Friday	34	11
Saturday	41	18

Note: During the middle of the week fewer occurrences and complaints happened. Saturday is the day of most frequent complaints and most numerous odor occurrences.

Table VII—Effect of the Time of Day

Time of Day	Number of Complaints	Number of Nuisance Occurrences
0000 to 0600	12	9
0600 to 1200	29	23
1200 to 1800	44	24
1800 to 2400	53	32

Note: Only 8.7% of complaints and only 10% of the odor occurrences came during the first quarter of the day.

Table VIII—Effect of Temperature

Temperature Range	No. of Complaints During 1958 and 1959	No. of Hours of Temp Occ	Ratio: No. Hours/No. Comp
0 to 44	0	6184	Inf.
45 to 49	2	1262	631
50 to 54	3	1121	374
55 to 59	4	1118	280
60 to 64	5	1493	299
65 to 69	26	1795	69
70 to 74	33	1957	59
75 to 79	34	1228	36
80 to 84	13	817	63
85 to 89	10	472	47
90 to 94	4	73	18
95 to 100	0	0	..

Note: The critical temperatures for these odor nuisances are above 65°F. Higher temperatures result in more frequent complaints and nuisances.

Table IX—Effect of Atmospheric Pressure

Pressure Range (In. Hg)	No. of Complaints During 1958 and 1959	No. of Hours of Pressure Occ	Ratio: No. Hours/No. Comp
0 to 2884	1	1234	1234
2885 to 89	6	790	132
90 to 94	21	1424	68
95 to 99	9	1714	190
2900 to 04	18	2032	113
05 to 09	25	2260	90
10 to 14	18	2090	116
15 to 19	15	1770	118
20 to 24	9	1720	191
25 to 29	5	844	170
30	4	1622	406

Note: Very few complaints were received when the atmospheric pressure was below 28.84 in. Hg.

Table X—Effect of Relative Humidity

Relative Humidity Range	No. of Complaints During 1958 and 1959	No. of Hours of R.H. Occurrence	Ratio: No. Hours/No. Comp
0 to 30	0	453	Inf
30 to 49	27	2974	110
50 to 69	47	5186	110
70 to 79	24	3184	132
80 to 89	18	3007	167
90 to 100	18	2698	150

Note: Hours of low relative humidity have more frequent complaints per hour.

Table XI—Effect of Wind Velocity

Range Wind Velocity, Mph	No. of Complaints During 1958 and 1959	No. of Hours of Vel Occ	Ratio: No. Hours/No. Comp
0 to 4	25	3584	143
5 to 14	95	11105	117
15 to 24	17	2740	161
25 to inf	0	91	?

Note: Wind velocity had no effect on the number of hours per complaint.

Table XII—Effect of Changing Temperature, Pressure, and Relative Humidity

Type of Change	Temperature		Pressure		Relative Humidity	
	No. of Complaints	% of Total	No. of Complaints	% of Total	No. of Complaints	% of Total
Increasing	34	26	64	49	69	52
Static	19	14	37	28	15	11
Decreasing	79	60	30	23	48	37

Note: On a percentage basis, decreasing temperature, increasing pressure, and increasing relative humidity cause more frequent complaints to be received.

nuisance occurrences in this type of industry are:

1 Months of the year—June, July, August, and September
2 Days of week—Friday, Saturday, Sunday, and Monday
3 Time of day—the PM hours
4 Temperature—65° and over
5 Pressure—28.84 in. Hg and over
6 Relative humidity—particularly the lower ones
7 Wind velocity—has no significance
8 Changing temperature—decreasing
9 Changing pressure—increasing
10 Changing relative humidity—increasing

The data in this study were gathered so that parallels from it might be drawn. By watching these meteorological factors, odor nuisance occurrences can be forecast with some degree of accuracy. These results, however, were obtained specifically on a meat rendering plant operation and care must be taken when drawing parallels with other types of industry.

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Committee Announced For APCA Membership; Drive Soon Underway

At the recent Board of Directors Meeting held in Pittsburgh, Dr. W. L. Faith, First Vice President of APCA, announced that he had staffed his membership committee, with the exception of two or three additional members.

He reported that the committee will commence a concerted membership drive as soon as the balloting on membership dues increase has been completed.

The campaign will be sparked by the following members, based on industry as well as sectional representation: W. L. Faith, chairman, W. J. Barrett, Humberto Bravo A., J. F. Conlon, B. E. Crawford, D. L. Davis, H. E. Friedrich, E. R. Hendrickson, G. A. Howell, R. L. Ireland, W. C. Johnson, John G. Liskow, W. E. McCormick, Walter Rauh, Casimir A. Rogus, August T. Rossano, Jr., Charles E. Roth, M. L. Sanvito, Sr., E. F. Scherr, Ellis E. Smauder, D. H. Wheeler, Ralph L. Weimer, Austin Heller, and C. C. Tate.

OPEN FOR SUGGESTIONS

The time is fast approaching when a new president and five new APCA Directors will be elected by the membership. You, as an individual member or company representative member of APCA, are requested to submit to the chairman or any member of the Nominating Committee, names of individuals and the offices for which you feel they are qualified. These recommendations should be received before March 1, 1961.

The members of the Nominating Committee and their addresses are as follows:

Ralph W. Bourne, Chairman
Chief Engineer
Air Pollution Control District
Jefferson County
304 City Hall
Louisville, Ky.

Richard J. Ruff, President
Catalytic Combustion Corp.
4544 Grand River Ave.
Detroit 8, Mich.

Harry C. Ballman, Director
Air Pollution Control Department
National Coal Association
Marketing Division
Coal Building
1130 17th Street, N.W.
Washington 6, D. C.

Richard F. O'Mara
O'Mara and Flodin, Inc.
1111 Wilshire Blvd.
Los Angeles 17, Calif.

James H. Carter
Smoke Commissioner
City Hall, Room 419
St. Louis 3, Mo.

The offices for which this committee is to select nominees are:

1. President—to serve one year.
2. Eight Directors—to serve according to the following schedule:
   Two control officials to serve three years.
   One control official to serve two years.
   One control official to serve one year.
   One representative from research, educational, and consultant category to serve three years.
   Three industry representatives to serve three years.

Retiring Board members are: Dr. Leonard Greenburg, research, educational, and consultant category; Louis E. Bunts, Richard E. Hatchard, Ralph W. Bourne, and Raymond Smith, control officials; C. C. Tate, petroleum, Max W. Lightner, steel, and John M. von Bergen, equipment—industry.

The large number of Board members who are being elected is occasioned by the change in by-laws two years ago combined with the re-alignment of the Board due to Dr. Greenburg's change in employment category.

VARIATION *of* DIFFERENT POLLUTANTS *in the* ATMOSPHERE *of* MEXICO CITY*

HUMBERTO BRAVO A., Chemist, Air Pollution Department, Instituta De Ciencia Aplicada, Coudad Universitaria, Mexico D. F.

Demonstrative data on the existence of the air pollution problem in Mexico City were presented in an earlier report.[1] Data presented in the present survey concern particles collected by sedimentation, material suspended in the air collected by filtration and its contents of organic material (benzene soluble), smoke concentration, and levels of some gaseous pollutants.

The sampling program was carried on at two distinct sampling stations. One is located in the N.N.W. area (Tacuba), which borders one of the heavier industrial zones. The other station is located in the S.W. area which is a residential zone, University City (Fig. 1).

Material Collected by Sedimentation

The wet type fall out device was used with water as the collector medium and with mercury chloride as bacterial preservative. Figure 2 is a comparative graph, representative of the monthly deposit of material during a year (1959).

An increase in the amount of material collected during the rainy season (April through August) due to the wash-out effects is observable, the contamination effect of the industrial N.N.W. area in the surrounding localities due to prevailing winds (N.N.W.) is also appreciable and the screening effect that the city has on the atmospheric dust is shown because of the differential amounts of collected material in those stations.

Material Suspended in the Air

This material is collected by filtration, using a high volume sampler (Staplex), with a fire fiber glass filter. It is assumed to have a very low content of organic material and good retention for particles as small as three microns of diameter. The volume of air sampled is about 1056 m^3 and the amount of material collected is determined by weight. Figure 3 gives an idea of the amount of suspended material in the air during the different months of the year (1959). The data show decreasing values during the rainy season (April through August) and high values during the dry months.

The maximum peaks may be attributed, in short, to general meteorological conditions.

The material collected by air filtration is extracted with benzene for eight hours (Soxhlet extractor), and a separation in the different organic fractions is carried on by a differential solubilities method.[2] The result from the analysis of the neutral fraction† is shown in Fig. 4, which represents a comparison to the composition of other neutral fractions from U. S. cities.[3] A high content of aromatic material (52%) in the fraction corresponding to Mexico City is to be noted.

Smoke Concentrations

This sampling was done using a smoke sampler (Research Appliance Co.) with Whatman filter paper No. 4. The spots were estimated by a photoelectric device, and the results are reported in Coh/1000 ft. Figure 5 shows the varia-

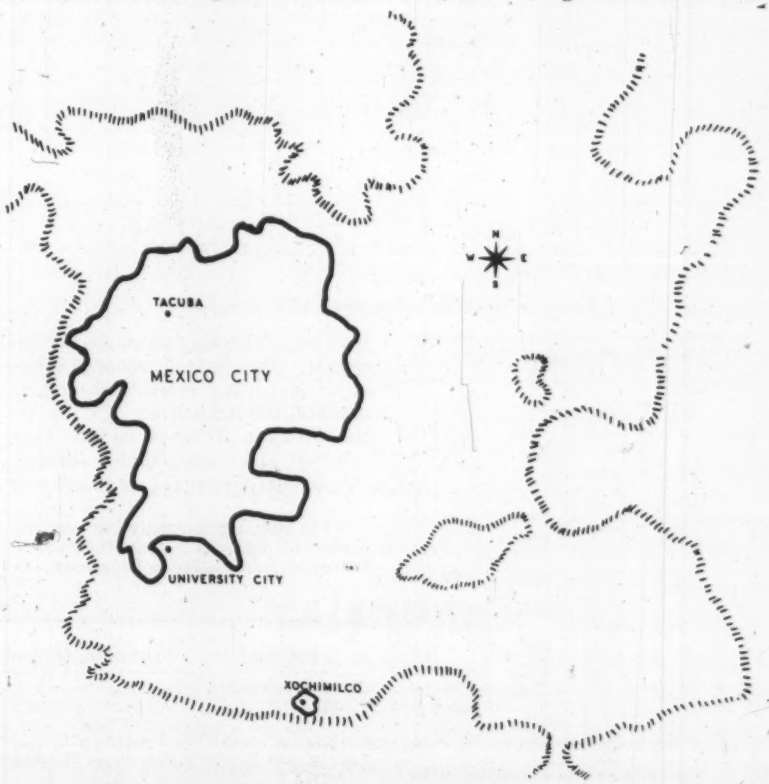

Fig. 1. Localization of sampling sites.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

† The analysis was carried on at the Robert A. Taft Sanitary Eng. Center, Cincinnati, Ohio.

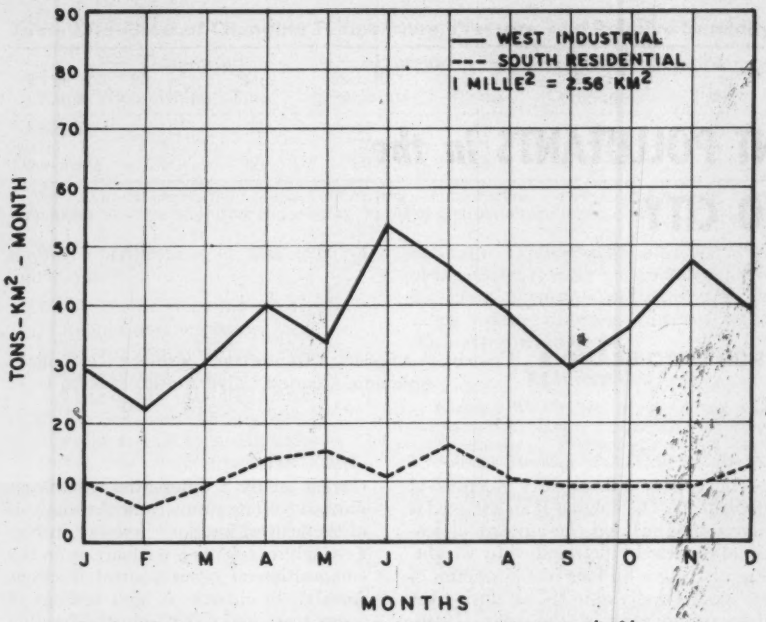

Fig. 2. Monthly deposit of material collected by sedimentation tons/km²/month.

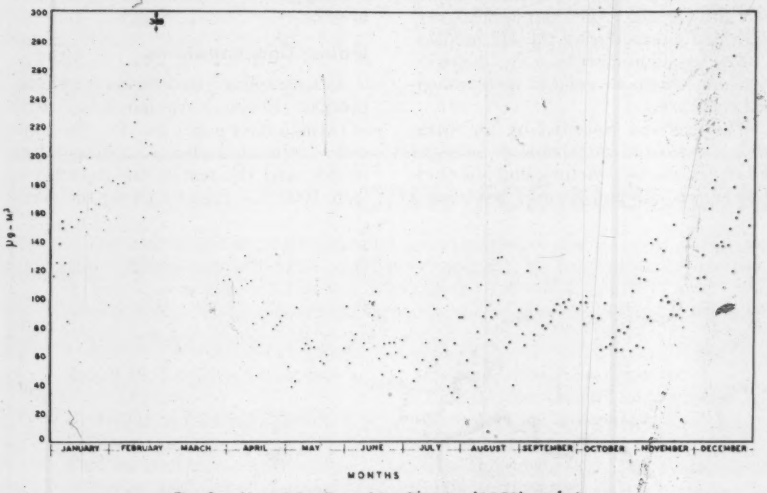

Fig. 3. Material collected by filtration (1959) mg/m³.

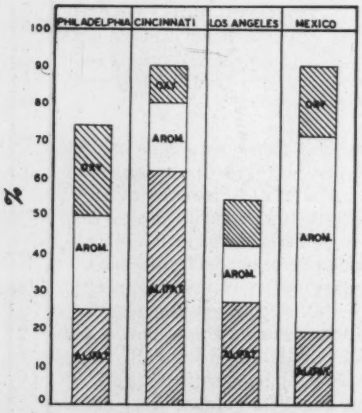

Fig. 4. Comparison of the composition of the neutral organic fraction in different cities.

tions of smoke concentrations for December. Two peaks of maximum values are observed; one in the early morning (05:00–07:00 hr) and the other in the late afternoon (17:00–20:00 hr). Considering the topographic situation (Mexico City is located on valley floor terrain), we believe that the first peak results from the phenomena known as Hewson Fumigation were aggravated by low air velocity at this time of the day. The second peak of maximum concentration could be the product of industrial and business activity associated with the micrometeorological features of the area under study.

Gaseous Pollutants

To understand the nature of the gaseous pollutants in the atmosphere of Mexico City, a sort of exploratory survey was made (Table I represents the values obtained for different gases and methods used for their detection).

Since the SO_2 concentrations are high in comparison with some U. S. cities, more attention was drawn to this particular pollutant; a simultaneous sampling was done in the two already mentioned stations (Tacuba and University City*). The extent of this sampling was a six-month period. Figure 6 gives the maximum and average values per month of sulfur dioxide in the two stations (at 11:00 hr). It is not difficult to notice in this figure that the contamination is highest in the Tacuba Station (N.N.W. area).

Figure 7 shows the fluctuations around the clock in the month of September, 1959; also two maximum peaks are present as in the smoke concentration and the same explanation seems to fit for the SO_2 concentration.

With respect to the oxidant values (1 pphm) obtained in Mexico City, they seem to be lower than in noncontaminated areas where values as high as 5 pphm were found.

Conclusions

It is noticeable that while SO_2 concentrations are high (average 0.161 ppm) the concentrations for oxidants are really low (average 0.01 pphm) even in comparison with noncontaminated areas.

The variation of suspended material and gaseous pollutants (SO_2) in the air presented two maximum peaks, which are thought to be the results of micrometeorological conditions and human activities. Concentrations of SO_2 as high as 1.3 ppm during the month of April were found in the Tacuba station area and a slight increase in the same month was found in the University City which made us think that this SO_2 contamination comes mainly from the

* The sampling and analytical work was carried on by A. P. Báez, Instituto de Ciencia Aplicada, Mexico University.

Table I

Pollutant	Detection Method	Concentrations, Ppm by Vol Max	Min	Average
Oxidants (03)	K.I.	0.044	0.000	0.010
SO_2	(a) Steigmann (b) West	1.60	0.000	0.161
NO_2	Saltzman	0.3777	0.005	0.0922
$CH_2{=}O$	Sodium bisulfite	0.760	0.00	0.239
NH_3	Nessler	0.237	0.00	0.022

N.N.W. area and is diluted through the city, because of the prevailing winds. The concentrations of suspended material reach values as high as 389 $\mu g/m^3$ during the dry months. It is observable in the decrease of the amount of collected material during the rainy season (April through August). Then two fundamental annual cycles are present referring to material suspended in the air.

The amount of gravity collected material shows the great influence that the west industrial area and meteorological factors have on the atmospheric pollution in Mexico City.

This short survey shows that at the present time the air contamination in Mexico City is as serious as in many cities of the U. S. and sufficient contamination exists to give consideration to the initiation of an air pollution control program in Mexico City.

Acknowledgments

The author wishes to offer sincere thanks in their co-operation throughout the study to: Dr. Gustavo Viniegra, Industrial Hygiene Director, S.S.A.; A. P. Báez, Head of the Chemistry Section of the Instituto de Ciencia Aplicada, University of Mexico; and co-workers of the Industrial Hygiene Laboratory.

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(*Continued on p. 467*)

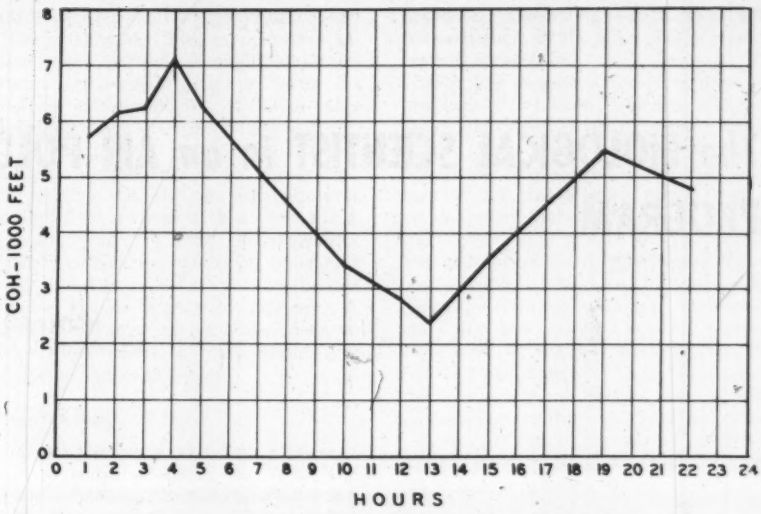

Fig. 5. Variation of smoke concentration (December, 1959).

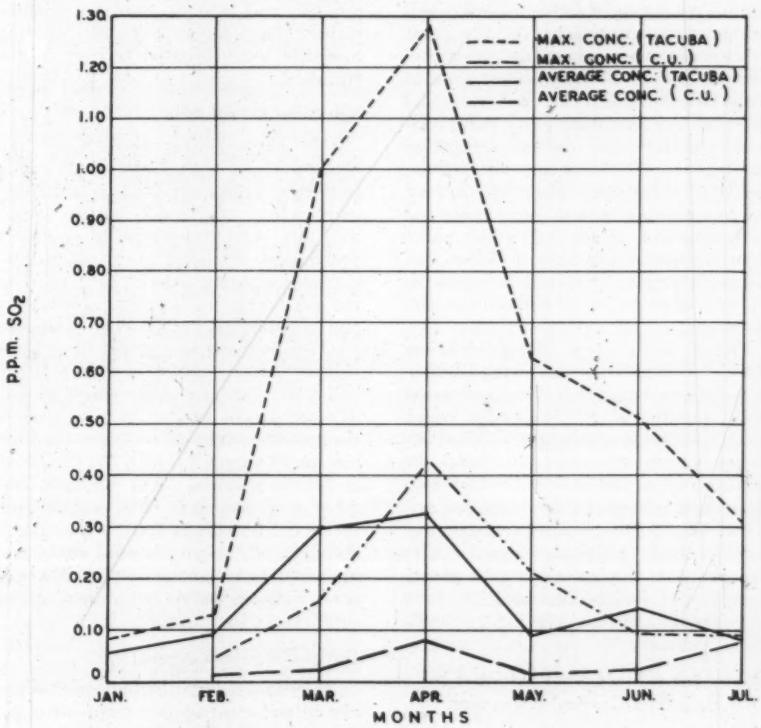

Fig. 6. Values of SO_2 in two stations (Tacuba and University City).

ANALYZING METHODS

(*Continued from p. 435*)

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CALENDAR

April 18–20, 1961	International Symposium on Chemical Reactions in the Lower and Upper Atmosphere, Stanford Research Institute, Menlo Park, California.
June 11–15, 1961	**54th Annual Meeting of APCA, Hotel Commodore, New York, New York.**

The BIOLOGICAL SCIENTIST *in an* AIR POLLUTION CONTROL PROGRAM*

HOWARD A. JAMES, Director of Statistical Services,
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The expansion of the field of air pollution into many disciplines has fathered a family of technical and quasi-technical papers which give the point of view of the person writing from within one of these disciplines. They seem to have titles such as "The ———— Aspects of Air Pollution," or "Air Pollution Control from the Standpoint of a ————." This paper is yet another of this type. However, instead of generalizing about how biological scientists look at the field of air pollution, an attempt is made to show how one particular biological scientist is utilized in an active air pollution control program.

What, then, is a biological scientist? Webster's International Dictionary defines biology as "the science of life; the branch of knowledge which treats of living organisms." The biological scientist might be best described as a life scientist. However, the usual collegiate curriculum for any of the life sciences requires a background of the basic physical sciences. This should place the biologist in the unique position of being able to have some grasp of both fields—or at least a working vocabulary.

Need for a Biological Scientist in Air Pollution Control Programs

In the rapidly expanding field of community air pollution control, most control authorities in the past have been limited to urban areas, mainly industrial in nature. In these organizations the engineer was the backbone. Agriculture had fallen victim to industry in certain areas, particularly when adjacent to large smelting operations. The Selby and Trail investigations gave the biologist-scientist a prominent role because of extensive vegetation damage. The sources of pollution were pinpointed, and in most instances specific rather than community-wide control measures were initiated to correct the situations.

Agricultural Problems

The skyrocketing population has brought about the growth of air pollution from large residential communities surrounding the older urban areas. The new community-type of pollution problem has extended into the surrounding agricultural areas which provide the perishable fresh fruits, vegetables, and ornamentals for the city. Damage to these products has caused these agriculturists more economic loss from air pollution than any other single group. The problem of communication between the grower and the air pollution engineer has raised a barrier which has produced a serious problem. The biologist can be of great service to both parties since he should be able to have some understanding of the agricultural problems, and yet have enough of a physical science background to present these problems to the engineer.

Duties Differ with Areas

The exact role of the biological scientist in a control agency varies with the type of area in which he is employed. In a strictly urban district he may find that he is charged mainly with gathering public health information as to the human physiological response to certain air pollutants. He may also receive the inquiries from local garden clubs and horticulturists.

In another instance he may find that he is assigned to a rural area which suffers from one or several industrial sources where agriculture is the principal victim. There his work may largely be confined to agricultural damage from one or more known pollutants.

The third type of situation which comes to mind is the large district which embraces industrial, residential, and a wide variety of agricultural developments. This type of area is exemplified by the Los Angeles Basin and the San Francisco Bay Area. In these two areas we find a combination of the above two situations, with the addition of the agricultural and health problems arising from area-wide pollution.

This report concerns itself with the problems facing a life scientist—specifically a biostatistician—in the Bay Area Air Pollution Control District in California.

Bay Area Air Pollution Control District

The Bay Area Air Pollution Control District covers six counties with a total area of just under 3800 sq mi of land area and a population in excess of 3¼ million people. The topography ranges from sea-level up to 4200 ft. The annual rainfall ranges from approximately 12 in. in one part of the area up to approximately 60 in. in another. Just under two-thirds of the area is devoted to agricultural endeavors ranging from beef cattle to orchid culture. These variables have presented a wide variety of problems related to air pollution.

The first assignment of the newly organized district was to draft the control regulations and it was necessary to gather information as to the sources of pollution and what damage it was doing throughout the area. The district staff was built around a nucleus of engineers and chemists. Since it was a new organization and the position of statistician had not been filled, it was decided to employ a biostatistician. These duties were to include investigation of the air pollution problems of and from agriculture.

To date the only regulation enacted imposes a band on open burning. Agri-

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

culture, with the exception of greenhouses, is exempted from this regulation because alternate methods for the disposal of most agricultural wastes have not yet been developed. These exemptions are up for review every two years. The control regulation for industrial and commercial sources is in the midst of public hearings before enactment.

Assigned Role in the Bay Area Air Pollution Control District

The biologist-scientist role in the District is part of the job of the biostatistician with a biochemical-bacteriological-public health background. One of the first needs was to learn to identify certain types of air pollution damage to specific indicator types of plants. The generous assistance from experts from Standard Research Institute and the Agricultural Extension Service of the University of California provided introduction to a basic group of common plants with the most easily identifiable symptoms. This information was augmented by visits with plant pathologists and field technicians at the University of California, Riverside, and at the Los Angeles County Air Pollution Control District. Some of the Bay Area's commercial flower growers who had been suffering from air pollution damage provided additional information. A working relationship was established with several growers who report their losses by mail or telephone. At the same time liaison was established with the various Farm Bureaus, Farm Advisors, Agricultural Commissioners, Cattlemen's Associations, and individual people in the agricultural industry.

Personal Contact

Personal contact with these groups provided an opportunity to familiarize them with air pollution control. Often, these groups of people had not fully realized that they were not only the victims, but were also contributors. Many of these had damage to their crops which they had not recognized as being caused by polluted air. The District contains one of the Nation's largest cut flower growing areas. This multimillion dollar crop has suffered large losses—particularly among the orchid, rose, and carnation growers. Truck-farms have also been victims. The biologist investigates these complaints and endeavors to determine whether the damage is from air pollution or from other factors. When the type of damage is not clearly related to air pollutants the matter is referred to the Agricultural Commissioners or Farm Advisors of the county. This personal relationship bore fruit when one small segment of the greenhouse operators tried to repeal the ban on open burning and most of the other growers came to the defense of the District's stand. This co-operative attitude was partially brought about by some understanding of problems involved in agriculture. Although this biologist is not an expert in horticulture, the background in the life-sciences helped in following their reasonings. In dealing with living systems, it is essential to remember that there are a great number of uncontrollable variables which can give rise to not only black and white relationships, but also to the unlimited shades of gray in between. A genuine interest and an eagerness to learn does much to bring about and continue this relationship.

Brush Burning

Brush burning is considered a phase of the agricultural exemption from the open burning ban only so long as it is a part of a continuing agricultural operation. This does not cover the burning of land-clearing debris for industrial or housing developments. In a few instances the District Hearing Board has granted variance for such burning when they felt that burning was the only feasible method of disposal and where weather conditions during the burning would preclude nuisance to others. The biologist has been involved in several of these hearings to support the District council with testimony and/or information because of similarities in the emission of such open fires with those from agricultural fires. The biostatistician is also asked to design sampling surveys to assess the contribution to localized and area-wide air pollution of any such burning under a variance.

Statistical Duties

In the Bay Area Air Pollution Control District, and perhaps uniquely so, the Biological and Statistical duties are combined into one office. It was felt that a biostatistician could provide both of these services if certain portions of the routine statistical calculations were handled by a trained mathematician-assistant. The statistical duties include a wide variety of interesting problems. Some of those are briefly described.

The statistical tabulation and analysis of weather data from various weather bureau stations in the District, as well as those data generated by the District's station, have been largely handled by the mathematician-assistant in close co-operation with the Air Analysis Section and with some little assistance from the statistician. This same arrangement has been used in the evaluation of certain air pollution monitoring methods.

The data collected by the District's principal engineers on sources of air pollution emissions have been evaluated to assist them in the writing of the new control regulation.

Sampling networks for a variety of problems have been designed. These range from fluoride to particulate sampling. These particulate fallout sampling trials have ranged in size from the burning of a single brush pile to range brush control fires of 1200 acres. All of these were in irregular terrain where classical concentric-ring networks were not possible. Cloud travel over such ground is still an uncertain measurement for the Army Chemical Corps after over 40 years of field trial experience. The study of these fires and their resulting ash fallout were a responsibility of this section on two counts: (1) brush burning is an agricultural problem for the cattle men, and (2) sampling network design was a part of the statistical responsibility. In the several instances where variances have been granted for open burning of brush piles, the network design and much of the actual field sampling were carried out by the statistician.

The development of a district-wide sampling network for suspended particulate matter was another of the statistical duties. Field trips were made to establish these sites and to secure co-operation of volunteers to activate these samplers at a predesignated time. This also provides valuable contacts with a number of people and interests them in pollution control. After the initial sampling the field work was carried out by the Air Analysis Section.

Vegetation damage from air pollutants has been surveyed on District-wide basis and on a local nuisance complaint basis. Again, in these instances, the statistical as well as biological aspects were considered.

All of these problems have dealt with sampling and evaluation, but there is another important side of the statistical duties. This phase does not require much field work, other than consulting. The design of the information retrieval systems involved in the registration of pollution sources in the district is of major importance. This involves not only the design of the filing-retrieval system, but also the design of the various forms used to gather and record the information. Within this system there needs to be the incorporation of source testing data, air monitoring data, enforcement information, legal data, and a method of retrieval for statistical evaluation. A District of this size requires a mechanical or electronic punch-card system to handle the large amounts of data. With the ever-present budget limitations, it is necessary to achieve the maximum usefulness from any system at a minimum of expense. In order to achieve greater usefulness from the

equipment, systems are also being investigated to handle other problems such as library search, mailing lists, etc.

The statistician is also called upon to participate or observe in special conferences and meetings where his statistical reasoning might prove useful.

The biostatistician must not only develop a list of consulting contacts in the agricultural and health fields, but he must also develop the same resources in the statistical specialties.

The incentive to develop new statistical techniques and to utilize new applications of known techniques is always present. Little of this work has been carried on to date since more pressing applied statistical problems have monopolized the available time. This phase of the work is expected to play a larger role in the future.

Surveys and Studies

Several District-wide surveys have been made following the periods of highest oxidant reading to determine the geographical extent of vegetation damage. Selected indicator plants are examined at or near predetermined sites for typical damage. At least two different types of indicator plants must show damage at each site to be considered an affected area. Negative findings do not necessarily mean a "photochemical-smog-free" area but only indicate that those plants examined were not marked at the time of examination. The sites where damage was observed were felt to be indicative of plant damaging levels of pollutant within a period related to the specific species. Such markings have been found from sea level to the top of Mt. Hamilton, at 4200 feet. These surveys have been conducted in the late fall when the District oxidant readings are usually highest. Certain areas where damaged vegetation was not found in the fall surveys are known to be affected at other seasons when the prevailing wind pattern changes. These same indicator plants are examined whenever other field trips present the opportunity.

Certain plants are highly sensitive to ethylene and provide a means of rough estimation of the relative levels of this olefin. Several orchid growers in the District send their daily loss and harvest figures into the office. These data provide a retrospective estimate of the ethylene problem. Greenhouse operators with roses, carnations, snapdragons, and bedding tomato and pepper plants provide reports to augment these data. These figures are now being studied for correlation with weather data.

Cases where agriculture believes that losses are due to air pollution are investigated. These range from fluoride contaminations of orchards and pasturage to the drift of chemical weed killers onto susceptible crops. Each of these reports requires individual treatment which may or may not include the design of a sampling network with support from the district's Air Analysis and Laboratory sections. Even in cases where current regulations do not control the specific pollutant, a public service is sometimes carried on to assist local enforcement agencies or agricultural groups.

Another duty of the biometrician involves the study of agricultural data concerned with waste disposal problems from greenhouses. On this project the University's Agricultural Extension Service staff and the Agricultural Commissioner's offices provided most of the field contact work and data gathering.

Duties Include Public Relations for New District

Part of the duties include specific public information and education work since the district is relatively new. Many of the growers have been misinformed, or do not even realize that our agency exists. These contacts provide an opportunity to establish a friendly relationship and achieve better voluntary control measures without strong enforcement action. Invitations to attend and/or speak at meetings provide an excellent opening for a good working relationship with a wide variety of people. These often provide an insight into local problems before they erupt into local issues. In this phase of the work, it is essential that the biologist has a firm belief in air pollution control. It is mandatory that he be willing to listen to the beliefs of those people and that he does not appear to "talk down" to them. A long series of degrees does not impress agriculturists if the "expert" cannot even grow crab grass. He must remember the lesson learned from the Public Health people—that you receive much better lasting co-operation from everyone if you can persuade people that they should voluntarily prevent air pollution for their own good, as well as the community's good, rather than depend on the police powers of their district. A "thou shalt not" attitude will nearly always arouse antagonism and create a rebellious response.

Another role that the biologist must play is that of the eyes and ears in his specialty for the air pollution control officer and other members of the staff, as they all serve the legislative Board of Directors. He must screen his information for bias and chaff and assist these people as an information source. He must be prepared to defend his advice whether in staff meetings, board meetings, or in court as an assistant to council.

Co-operation with Other Areas

He should avail himself of every opportunity to increase his knowledge in the field and read as widely as time permits. A free exchange of information with others in the field is greatly desired. A co-ordinating committee is being organized from several control and research organizations in California and will establish an information center on air pollution problems in agriculture. The Bay Area Air Pollution Control District is one of the contributing organizations. His attendance and participation at national, state, and local organization meetings is most desirable.

Importance of a "Bio-Outlook"

Perhaps the most important role of the biological scientist is that of providing a "bio-outlook" on pollution control problems. In this particular district it includes a statistical outlook as well. This may appear to be a simple thing. However, most engineers are trained to be readily able to establish the limits of uncontrollable variables. They are usually able to reproduce a situation on a pilot plant scale before setting up a full scale operation. Those in the "biosciences" are not only afflicted with more variables, but are often dealing with a one-time phenomenon. These occurrences which are of little statistical value are often worth reporting. This is common practice in the medical and dental journals. To those in the biological sciences this type of reporting is very important. To many engineers, if it cannot be expressed by an equation, it is useless. Here is the biological scientist's important role of attempting to reconcile these widely divergent views. In general, most engineers have a very meager background in the life sciences while the life scientist usually has had at least an introduction to physics, chemistry, and some higher mathematics. He has some familiarity not only with the vocabulary used by the engineer, but also with that used by the horticulturist. He, therefore, becomes the translator of the language and also the translator of concepts. The biostatistician must be able to explain why he must have one sample size for a reliable analysis of engineering data and another for biological data.

The biometrician should be familiar with the demographic data of his district. He is usually charged with the accumulation of these data and the presentation of its relationship with air pollution levels. He must also be prepared to analyze engineering, meteorological, sampling, and economic data submitted to him. In addition, he should be prepared to present these to his superiors and the public in a graphical, understandable form. He may be called upon to assist in the design of

(*Continued on p. 467*)

STANDARDS for AIR QUALITY in California*

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During the past few years there was a growing interest in standards for air quality in California communities. The State Department of Public Health's Advisory Committee on Air Sanitation in 1958 recommended to the Department that it undertake the task of setting standards for air quality which would act as guides to local air pollution control programs. The Assembly Interim Committee on Public Health in its 1959 report to the Legislature also recommended that air quality standards be set.[1] In fact, that Committee went so far as to suggest standards for some pollutants. Even prior to the interest of the Department's Advisory Committee and the Legislative Committee, the Los Angeles County Air Pollution Control District had adopted alert levels.[2] Although these levels were not standards for air quality, they established concentrations for four pollutants as a basis for community action to prevent a possible disaster.

The interest in air quality standards has been an outgrowth of the air pollution problem in California. Although the most serious problem is found in Los Angeles, air pollution levels sufficient to cause eye irritation, vegetation damage, and reduced visibility have been experienced in all the larger metropolitan regions of the State. With the widespread occurrence of air pollution and the knowledge that motor vehicles are an important source of pollutants, it was recognized that a more uniform statewide approach to the problem was needed. As a result, the 1959 State Legislature required that the California State Department of Public Health adopt and publish standards for the quality of the air of the State. Assembly Bill No. 1386 enacted by the Legislature states:

"The State Department of Public Health shall, before February 1, 1960, develop and publish standards for the quality of the air of this State. The standards shall be so developed as to reflect the relationship between the intensity and composition of air pollution and the health, illness, including irritation to the senses, and death of human beings, as well as damage to vegetation and interference with visibility."

The act also provides that the standards may be amended from time to time and that they shall be adopted after public hearings.

Other Standards

It has been found advantageous to adopt standards in a number of fields. A very common one is the speed limit on highways. Others include standards for electrical wiring and plumbing in buildings, foods and drugs, and professional licensing. Standards also have been adopted on the chemical and bacterial quality of drinking water, bacterial quality of milk and shellfish, radioactivity, sewage disposal, and the quality of the air for industrial workers. These standards have served a useful purpose in providing guidelines for planning and carrying out environmental santitation programs to protect the public health.

To date, little has been done in this country for the air in communities. The State of Oregon made a start when it established levels for particle fallout and suspended particulate matter.[3] Table I shows the levels that were set and how these provide for different values in industrial and residential areas.

Concentrations for four substances—ozone, oxides of nitrogen, sulfur dioxide, and carbon monoxide—were established in 1955 by the Los Angeles County Air Pollution Control District as part of an alert system.[2] The concentrations set for the three alert levels are shown in Table II. As has been stated, these concentrations were not intended to include all the effects that were considered in the State Department of Public Health standards but were for the purpose of preventing a possible disaster in Los Angeles County. Following adoption of the State air quality standards, that District amended the carbon monoxide alert values to include a concentration and time of exposure.[4]

Another ambient air standard that should be mentioned is that for beryllium. The Atomic Energy Commission recommends that the concentration of beryllium in the community atmosphere be below $^1/_{100}$ $\mu gm/m^3$ of air. This value is $^1/_{200}$ of their recommended level for the worker exposed to this material at his place of work.[5]

The Russians have set atmospheric standards for a large number of compounds. Recent translations of the Russian literature containing these standards have appeared in this country.[6] The levels adopted by the Russians are very low when considered in light of our knowledge of the toxicity and effects of many of the substances included. Further study and evaluation of the Russian literature are needed to determine if their findings are adaptable to our situation.

The largest volume of data available in the United States on air quality and its effect on individuals is in the field of occupational health. Threshold Limit Values for a long list of compounds have been adopted by the American Conference of Governmental Industrial Hygienists.[7] It would seem that concentration of substances used to protect the health of workers could be applied directly to the atmosphere of a community.

Table I—Permitted Particle Fallout Rate and Suspended Particulate Matter in Excess of Normal Background Values

Oregon Air Pollution Authority

	Residential or Commercial Land Use Area	Industrial Land Use Area
Particle fallout rate	15 tn/sq mi/mo	45 tn/sq mi/mo
Suspended particulate matter	150 $\mu gm/m^3$	250 $\mu gm/m^3$

* Presented at the 53rd Annual Meeting of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

Table II—Alert Stages for Toxic Air Pollutants
Los Angeles County
Ppm by Volume

	First Alert[a]	Second Alert[b]	Third Alert[c]
Carbon monoxide	100	200	300
Nitrogen oxides	3	5	10
Sulfur oxides	3	5	10
Ozone	0.5	1.0	1.5

[a] Close approach to maximum allowable concentration for the population at large. Still safe but approaching a point where preventive action is required.
[b] Air contamination level at which a health menace exists in a preliminary stage.
[c] Air contamination level at which a dangerous health menace exists.

This is not the case. Worker exposure is for an eight-hour day and five-day week. Industrial workers are not representative of the most sensitive or frail groups in our population and levels for industry are based on exposure to single substances. Consequently, the exposure of people at work is considerably different from that of populations subjected to a complex type of air pollution such as that occurring in California metropolitan regions. The American Conference of Governmental Industrial Hygienists recognized these difficulties when, in adopting the Threshold Limit Values, it stated—"They are not intended for use, or for modifications for use, in the evaluation or control of community air pollution or air pollution nuisances." Conversely, the standards for the quality of the air of communities cannot be used for evaluating the exposure hazard to individuals at their place of work.

Procedure Followed in Developing Standards

The procedure for adopting the standards included the accumulation and evaluation of existing information, a critical review of all data and proposed standards by responsible scientists, public hearings, and, finally, adoption by the State Board of Public Health on December 4, 1959. The Department's Advisory Committee on Air Sanitation advised in all steps of the standard setting. This committee was composed of individuals who have had wide experience in air pollution or a related field. The Department also appointed a technical group composed of individuals with experience in such fields as toxicology, medicine, and air pollution to provide information to the Department and to our Advisory Committee on Air Sanitation regarding specific pollutants and concentrations to be considered. The advice and assistance of experts from other parts of the country, the U. S. Public Health Service, universities, and research institutions were also sought.

The Department considered it essential that any standards set be based on sound data and concurred in by scientists in the air pollution and related fields. This requirement greatly limited the substances on which standards could be set. However, it was felt that the need for sound standards supported by technical data justified limiting the standards to relatively few substances.

In addition to published material in technical journals, information was available on air pollution levels over several years at a number of locations in the State. Data were also available on the occurrence of irritation to the eyes and respiratory system and damage to vegetation in several of the metropolitan regions where air pollution is a problem. Vegetation damage and eye irritation have been produced and observed in laboratory experiments. Since 1954 the Department of Public Health has conducted a number of epidemiological studies of population exposed to air pollution and supported studies on the health effects of air pollution.

In view of the inevitable human biological variability, it was decided to base the standards on groups of persons in the population who are most sensitive to air pollution effects, provided such groups are definable. It was apparent that one level could not define all the conditions included in the Legislative Act which stated that the standards shall "reflect the relationship between the intensity and composition of air pollution and the health, illness, including irritation to the senses, and death of human beings, as well as damage to vegetation and interference with visibility." Three levels of air pollutants were selected as follows:

1 *Adverse Level*—Level at which there will be sensory irritation, damage to vegetation, reduction in visibility, or similar effects.
2 *Serious Level*—Level at which there will be alteration of bodily function or which is likely to lead to chronic disease.
3 *Emergency Level*—Level at which it is likely that acute sickness or death in sensitive groups of persons will occur.

The three levels were not merely different degrees of severity but each represents qualitatively different effects. Mechanisms of damage to vegetation, discomfort, or reduced visibility in the "adverse" level may have little or no relationship to the responses of sensitive groups under the "serious" and "emergency" levels. In addition, each pollutant necessarily would not need to be included under all three levels. For example, carbon monoxide was not recognized to have effects defined at the "adverse" level. On the other hand, sulfur dioxide could be found at all three levels.

The standards adopted by the State Department of Health are somewhat unique in that they do not contain a factor of safety. The concentrations that were used represent what was considered to be the lowest values at which the defined effect could be experienced by sensitive receptors. Most other standards are levels where no effects would be expected.

Standards Adopted

The standards that were established by the Department are given in Table III. As has been pointed out, standards were set only for substances on which it was felt there were sufficient data. In addition, a number of footnotes were included. Some of these footnotes cover substances for which actual standards were not set but on which fairly extensive information was available. It is likely some of these substances will be included in the standards in the near future.

One of the considerations of the Legislature in requiring air quality standards was that they would be used to determine standards for motor vehicle exhaust emissions. The "oxidant index" and carbon monoxide levels in the air quality standards had a direct and important bearing on standards for motor vehicle exhaust emissions that were also developed by the Department.[8]

The "oxidant index" of 0.15 ppm, as measured by the potassium iodide method, was established as a standard for "photochemical smog." This type of air pollution results from a reaction in the atmosphere between organics and oxides of nitrogen. However, it is the secondary pollutants produced in the reaction that cause the typical "smog" effects. Establishment of a standard for this type of air pollution was difficult as the actual substances causing eye irritation and "oxidant-type" vegetation damage have not been definitely identified.

While oxidant is not a specific substance and not itself the cause of undesirable effects, levels of 0.15 ppm have been associated with eye irritation, vegetation damage, and visibility reduction in several regions of the State where community-wide air pollution is of concern. This value has been frequently exceeded in a number of places in California.

Oxidant measurements include ozone and nitrogen dioxide. However, the "oxidant index" was not established as a standard for these compounds. As motor vehicle exhaust controls are ini-

tiated, it is very likely that the photochemical reactions will be so altered that oxidant values of 0.15 ppm will no longer be associated with the present smog effects and a new standard will be required to define photochemical smog.

The carbon monoxide standard at the "serious" level was set at 30 ppm for 8 hr, or 120 ppm for 1 hr. Exposures to these concentrations will result in approximately 5% carboxyhemoglobin. This, together with other common exposures to carbon monoxide, was considered likely to result in alteration of bodily function in selected groups.

The carbon monoxide standard has been the subject of considerable discussion. The 30 ppm value for 8 hr has been exceeded a number of times in the Los Angeles area and resulted in a need to set motor vehicle exhaust standards for carbon monoxide. Data from other parts of the State are not available in sufficient detail to indicate if present carbon monoxide levels there also are in excess of the standard.

Sulfur dioxide was the only substance included at all the levels at this time. The "adverse" level for this compound was the least difficult to establish because of the relatively good information that existed on vegetation damage.

It can be argued that the "adverse" level for particulates is not a standard at all but rather a definition of an effect. Data were not available that permitted a standard in terms of weight, number, and size of particulates. However, the significance of reduced visibility in air pollution episodes in California was considered of sufficient importance to indicate a value for visibility at the "adverse" level. The requirement that relative humidity be under 70% was to exclude the possibility of visibility being reduced by naturally-occurring fog.

Table III—Standards for Ambient Air Quality

California State Department of Public Health
December, 1959

	"Adverse" Level Level at which there will be sensory irritation, damage to vegetation, reduction in visibility or similar effects	"Serious" Level Level at which there will be alteration of bodily function or which is likely to lead to chronic disease	"Emergency" Level Level at which it is likely that acute sickness or death in sensitive groups of persons will occur
Oxidant	"Oxidant index" 0.15 ppm for 1 hr by the potassium iodide method (eye irritation, plant damage, and visibility reduction)	Not applicable	Not applicable
Ozone		Note 1	Note 2
Nitrogen Dioxide		Note 3	Note 3
Hydrocarbons		Note 4	Note 4
Photochemical Aerosols		Not applicable	Not applicable
Carcinogens	Not applicable	Note 5	Not applicable
Sulfur Dioxide	1 ppm for 1 hr or 0.3 ppm for 8 hr (plant damage)	5 ppm for 1 hr (bronchoconstriction in human subjects)	10 ppm for 1 hr (severe distress in human subjects)
Sulfuric Acid	Note 6	Note 6	Note 7
Carbon Monoxide	Not applicable	30 ppm for 8 hr or 120 ppm for 1 hr (interference with oxygen transport by blood)	Note 8
Lead	Not applicable	Note 9	Note 9
Ethylene	Note 10	Not applicable	Not applicable
Particulates	Sufficient to reduce visibility to less than 3 mi when relative humidity is less than 70%	Not applicable	Not applicable

NOTES—STANDARDS

1 Ozone, at 1 ppm for 8 hr daily for about a year, has produced bronchiolitis and fibrositis in rodents (Stokinger, H. E., Wagner, W. D., and Dobrogorski, O. J., *A.M.A. Archives of Ind. Health*, 16: 514, 1957). Extrapolation of these data to man is difficult. Functional impairment data have been reported by Clamann and Bancroft (Clamann, H. G., and Bancroft, R. W., *Advances in Chemistry*, No. 21, pp. 352–359, 1959); at 1.25 ppm some effect is observed on residual volume and diffusing capacity. The variability of the tests was not reported. Additional data would be needed before a standard is set.

2 A value of 2.0 ppm of ozone for 1 hr may produce serious interference with function in healthy persons, and the assumption is made that this might cause acute illness in sensitive persons. (Clamann, H. G., *op. cit.*)

3 Five ppm of nitrogen dioxide for 8 hr will produce decreased pulmonary function in animals. Slightly more may produce pulmonary fibrosis (Stokinger, personal communication); nitrogen dioxide from air pollution exposures is usually combined with nitric oxide and ozone. More data on human exposures will be needed prior to setting a standard.

4 Hydrocarbons are a group of substances most of which, normally, are toxic only at concentrations in the order of several hundred parts per million. However, a number of hydrocarbons can react photochemically at very low concentrations to produce irritating and toxic substances. Because of the large number of hydrocarbons involved, the complexity of the photochemical reactions, and the reactivity of other compounds such as nitrogen dioxide and ozone, it is not yet possible to establish "serious" and "emergency" levels for hydrocarbons. From the public health standpoint, the concentration of those hydrocarbons which react photochemically should be maintained at or below the level associated with the oxidant index defined in the "adverse" standard.

5 Carcinogens include a few organic compounds such as some polycyclic hydrocarbons, and some metals such as arsenic and chromium. Studies on effects on such substances are currently under way, but there are not sufficient data, at present, to set standards. In the meantime, it is recommended that concentrations of carcinogens in air should be kept as low as possible.

6 A sulfuric acid mist level of 1 mg/M³ with an average particle size of one micron will produce a respiratory response in man (Amdur, M. O., Silverman, L., and Drinker, P, *Archives of Ind. Hyg. and Occup. Med.*, 6: 305, 1952). It is not possible to generalize from this for all air pollution conditions, because under natural conditions particle size will vary. Only with large droplets would sensory irritation be produced without other physiological effects.

7 A level of 5 mg/M³ of sulfuric acid mist for a few minutes produces coughing and irritation in normal individuals (Amdur, M. O., Silverman, L., and Drinker, P., *op. cit.*). Presumably, it could cause acute illness in sensitive groups of persons in a period of 1 hr.

8 Given certain assumptions concerning ventilatory rates, acute sickness might result from a carbon monoxide level of 240 ppm for 1 hr in sensitive groups because of inactivation of 10% of the body's hemoglobin. In any event it is clear that when a population exposure limit has been set for carbon monoxide, because of exposures from other sources, community air pollution standards should be based on some fraction of this limit.

9 It is clear that lead levels should be set on the basis of average values for long periods. While data are abundant concerning human response to eight-hour-a-day, five-day-a-week exposures, data are insufficient for the effects of the continuous exposure inherent in community air pollution. While laboratory studies will be pursued with vigor, it becomes very important that local agencies collect data on existing lead levels. Since lead exposures are from multiple sources, community air pollution standards should be based on a portion of the total limit for population exposure.

10 Ethylene causes severe damage to vegetation. Ornamental plants are severely injured by exposures from 0.2 to 0.5 ppm. Tomatoes and fruit are adversely affected at similar levels. Current work is expected to permit a standard to be set within a year.

Conclusions

It is hoped that air quality standards adopted by the California State Department of Public Health will be of value in the State's attack on air pollution and that they will promote studies and research needed to refine and extend the standards.

Standards must not be a substitute for knowledge and good judgment. They can only act as guides. As in the case for other standards, those for air quality are not precise figures below

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AUTOMOBILE EXHAUST *Particulates*— SOURCE *and* VARIATION*

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The gaseous components of automobile exhaust have been studied extensively to determine their contribution to air pollution problems, and many publications are found in the literature describing this work. The present study was conducted to learn something of the physical and chemical nature of the particulates emitted in automobile exhaust.

A previous paper[1] described the sampling methods which were developed, for use both with stationary engine tests and automobiles tested on a chassis dynamometer. Preliminary results were also reported, which indicated that particulates constitute approximately 5% (by weight) of the amount of hydrocarbon vapor emitted by automobile exhaust. It was further reported that the organic (benzene-soluble) portion of the particulates is composed primarily of lubricating oil or products of reactions in the combustion zone involving lubricating oil. This paper describes additional tests which were conducted to measure the chemical differences between the lubricating oil (precursor) and the organic particulates emitted by the engine, as a function of engine operating cycle, engine design variables and maintenance practices.

Sampling Methods

Particulate samples were collected by filtration on 8- by 10-in. sheets of glass fiber filter, using a Roots-Connersville positive displacement type blower as a source of suction. The design of the sampling equipment and the sampling techniques are more fully described in a previous paper.[1] Wherever possible, duplicate samples were taken and the results reported are numerical averages.

Grab samples of exhaust gases were collected, along with each particulate sample, in evacuated glass bulbs and retained for infrared analysis for total hydrocarbons in the exhaust gas.

Analytical Methods

Total Hydrocarbons in Exhaust Gas were determined by passing the gas samples through ascarite into an evacuated one-meter gas cell and determining the absorbance at approximately 3.45 microns. Since *n*-hexane vapor was used as a calibration standard, the hydrocarbon concentrations found were expressed as *n*-hexane equivalent.

Total Particulate Matter was determined by weighing the fiber glass filters before and after collection of samples, the gain in weight being particulate matter. The filters were conditioned before each weighing by exposing them in a room held at 70–75°F and 40–50% relative humidity for at least two days in order to establish moisture equilibrium. Successive weighings of blank filters indicated that weights were reproducible to within one to two milligrams by this method.

Organic Fraction of Particulate (Benzene Soluble Extract) was determined by extraction of the filter in a Soxhlet extracter with 100 ml of benzene for eight hr, followed by concentration of the particulate extract to 50 ml. A 10- or 20-ml aliquot of the extract was placed in a tared aluminum dish and the benzene evaporated on a steam bath. The remainder of the extract solution was retained for the analyses which follow.

Olefin Content of Organic Fraction was calculated from the iodine numbers, obtained by treatment of a five-ml aliquot of the particulate extract with one ml of Hanus Solution (Iodine-Bromine, prepared according to Association of Official Agricultural Chemists) for a period of 30 min, followed by addition of five ml of 20% potassium iodide, and titration of the liberated iodine with 0.01 normal sodium thiosulfate to the starch end point. Five ml of benzene were used for a blank determination.

Carbonyl Content of Organic Fraction was determined on a 10 ml aliquot of the benzene solution of particulate extract using a slight modification of the differential pH method for the determination of aldehydes and ketones developed by Roe and Mitchell.[2] The use of a 0.5 ml-sample beaker and holder accessory for the Beckman model G pH meter instead of the standard five-ml sample beaker made it possible to use one-tenth of the specified volume of diluted hydroxylamine hydrochloride solution and hence obtain a 10-fold increase in sensitivity. Roe and Mitchell used 11 ml of diluted hydroxylamine solution. A minimum of 0.05 micromole of aldehydes or ketones in 10 ml of solution benzene could be detected using this smaller volume. Trace quantities of organic acids do not interfere with the method. Mineral acids do interfere if present, but were not present in this particular application.

Free Acidity of Organic Fraction was determined as follows: 20 ml of 85% ethyl alcohol with five drops of a mixed indicator (0.025% cresol red and 0.075% thymol blue) in a 60-ml vial were adjusted to the blue end point with 0.05 normal sodium hydroxide. The solution was bubbled with CO_2 free air for mixing and to exclude atmospheric CO_2. A five-ml aliquot of the particulate extract was added to the neutralized solvent and titrated to the end point with 0.05 normal sodium hydroxide from a micro buret. A blank titration was made with five ml of benzene.

Lead Content of Particulate Matter was determined on a limited number of samples by flame photometry. The

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* Presented at the 53rd Annual Meeting of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

Note: This investigation was supported in part by Southwest Research Institute, and in part by Research Grant S-22, National Institutes of Health, U. S. Public Health Service.

Table I—Emission of Automobile Exhaust Particulates

Engine Description		Idle			30 Mph Cruise			50 Mph Cruise		
Make and Type	Compression Ratio	Total Particulate[a]	Organic Particulate[b]	Flow Rate[c]	Total Particulate[a]	Organic Particulate[b]	Flow Rate[c]	Total Particulate[a]	Organic Particulate[b]	Flow Rate[c]
1954 Chevrolet, 6 cyl	7.5 to 1	6.4	0.42	16	78	0.45	88	77	2.1	113
1954 Oldsmobile, V-8	8.25 to 1	18	3.4	24	20	0.83	36	50	0.43	69
1954 Plymouth, 6 cyl	7.1 to 1	7.1	0.72	15	30	1.7	38	116	0.65	71
1957 Chrysler, V-8	9.25 to 1	16	10	32	30	0.57	88	15	0.68	116
1957 Ford, V-8	8.6 to 1	8.6	1.4	19	52	11	48	245	16	75
1956 Oldsmobile, V-8	9.25 to 1	8.3	0.77	16	39	1.1	48	70	0.37	81

Engine Description		30 Mph Acceleration			30 Mph Deceleration		
Make and Type	Compression Ratio	Total Particulate[a]	Organic Particulate[b]	Flow Rate[c]	Total Particulate[a]	Organic Particulate[b]	Flow Rate[c]
1954 Chevrolet, 6 cyl	7.5 to 1	71	0.26	142	68	18	72
1954 Oldsmobile, V-8	8.25 to 1	293	1.5	134	77	65	27
1954 Plymouth, 6 cyl	7.1 to 1	268	0.85	137	34	16	27
1957 Chrysler, V-8	9.25 to 1	17	0.98	307	274	220	45
1957 Ford, V-8	8.6 to 1	206	4.3	282	572	560	28
1956 Oldsmobile, V-8	9.25 to 1	107	0.78	299	175	160	37

[a] Total Particulates, milligrams per minute of operation at condition noted.
[b] Organic Particulates (benzene-soluble), milligrams per minute of operation.
[c] Exhaust Flow Rate, cubic feet per minute, corrected to 60°F and 14.7 psia.

lead compounds were extracted from portions of the fiber glass filters, after benzene extraction, with hot 1-1 nitric acid, diluted to volume with distilled water, and analyzed with the flame photometer. Iron was determined semi-quantitatively on the same samples with the flame photometer. Results on lead content are expressed as lead compounds having an average lead composition of 62.6% (based on figures of $^2/_3$ being PbCl·Br and $^1/_3$ being NH_4Cl·2-PbCl·Br). This average composition was taken from data published by Hirschler, et al.[3] While this average composition is probably not true for all engines and operating conditions, it is sufficient if one considers other errors which could have occurred in the collection and analysis of the samples.

Average Molecular Weight of Organic Fraction of Particulate was determined on the nonvolatile residue remaining after evaporation of the benzene solvent. Only a limited number of samples were prepared for molecular weight determination due to the small quantities of organic matter present. The analyses were performed using an ebullioscopic method with dimethyl formamide as solvent.

Engine Tests and Discussion of Results

Series I

In this test series, samples were taken from six stationary engines mounted on a test stand with a dynamometer. Data from five of these engines were published in a previous paper[1] and some of the data are reviewed here although it is expressed in different units. Data from a 1956 Oldsmobile engine, which was not included initially, have been added.

The total particulate and organic (benzene-soluble) particulate emissions found are given in Table I. Although all engines used in these tests were in good condition and tuned to manufacturer's specifications there are considerable variations from one engine to another. These might be attributed to many factors such as type and design of the engine, age of the engine, minor variations in operating conditions, type of fuel and lubricant used, and many others.

The 1957 Ford engine gave results which are probably not the values which would normally be obtained due to the fact that it was a new engine which had only four hours operating time before these tests were made. An unusual observation was made with this engine, which was the production of copious quantities of carbon in all cycles except deceleration and idle. This might be attributed to the fact that the engine was not fully broken in. Normally, there was little visual blackening of the fiber glass filter by carbon in the particulate; in fact, most filters usually had a tan or gray coloration.

A point worth noting is the hemispherical combustion chambers of the 1957 Chrysler engine which were designed for more efficient fuel consumption; and indeed, the total particulate emissions from the acceleration and 50 mph cruising cycles of this engine were much less than that obtained from any of the other engines tested. Total gaseous hydrocarbon emissions in the exhaust of this engine were also very low.

Particulate olefin emissions were highest during the deceleration cycle, on a time basis, because the total particulate emission was greatest. Considering the possible reactions of lubricating oil in the combustion zone, there appeared to be a tendency toward greater olefin formation at higher engine temperatures, although this trend was not consistent. Apparently factors of engine design and combustion characteristics, apart from combustion temperature, also affect the formation of high molecular weight olefins from lubricating oil. No significant difference in total olefin emission was apparent from one engine to another. The concentration of olefins in the organic fraction showed a tendency to increase with an increase in operating temperature due to changes in either engine design or operating conditions, but some exceptions were noted.

Lead emissions were determined on the particulate samples taken from the 1954 Plymouth engine and are reported as lead compounds in Table II along with iron which was determined semi-quantitatively and reported as Fe_2O_3. Although some of the iron collected is believed to have originated in the sampling system itself rather than in the test engine, it is included here to assist in making a material balance. On a weight basis, lead compounds form a substantial portion of the total particulates, whereas iron compounds are relatively insignificant and probably come from rust particles that form in the exhaust system.

Series II

This experiment was performed, using a chassis dynamometer to stimulate three operating conditions on a six-cylinder 1950 model Ford pickup, with the objective of determining the effect of engine tune-up on particulate emissions.

The vehicle used in these tests was privately owned and used daily, primarily for transportation to and from work.

Table II—Lead and Iron Content of Exhaust Particulates[a]

Benzene-Insoluble Portion

	Idle	30 Mph Cruise	50 Mph Cruise	30 Mph Acceleration	30 Mph Deceleration
Lead[b] compounds, mg/min	4.8	22	97	216	13
Fe_2O_3, mg/min	0.2	0.6	1.0	4.5	3.6

[a] Samples obtained from 1954 Plymouth engine.
[b] Average lead content of the lead compounds is assumed to be 62.6%.

Table III—Effect of Engine Maintenance[a]

Determinations Made	Idle		30 Mph, Cruising		Mild Acceleration[b]	
	Before Tune-up	After Tune-up	Before Tune-up	After Tune-up	Before Tune-up	After Tune-up
Hydrocarbon in exhaust gas, ppm	960	750	410	480	530	520
Exhaust flow rate, cfm (60°F)	17	13	37	37	45	45
Total particulate, mg/min	14	7.0	36	22	226	93
Organic (benzene-soluble) particulate, mg/min	0.77	0.55	0.70	0.42	1.5	1.3
Analysis of organic fraction:						
(1) Olefin, micromoles/min	1.4	0.64	1.3	0.58	3.3	2.1
(2) Free acidity, micromoles/min	0.80	0.20	1.5	0.13	1.7	0.99
Air/fuel ratio	>15	11.9	14.9	1.43	>15	14.6
Exhaust gas temp at end of tail pipe, °F	98	126	348	410	455	478

[a] Conducted with a 1950 Ford 1/2-ton pickup truck, 6 cylinder.
[b] This operating condition consisted of a stimulated acceleration (at constant speed of 30 mph) with the vehicle on a chassis dynamometer. Due to limits of cooling available for the engine, it could only be loaded to the extent of 15 hp and 11 in. Hg intake manifold vacuum.

An initial set of samples was taken without changing any engine adjustments, after which the engine was given a complete tune-up. The observations and corrections made during the tune-up are summarized below:

1 Timing was advanced 5° from the basic setting, which was corrected.
2 Point gap was 0.018 in. Replaced points and condenser. Set new points at 0.025 in. (manufacturer's specification).
3 Spark plugs, as removed, had gaps varying from 0.025 in. to 0.036 in. (none correct) and average breakdown pressures of 75 psi. Cleaned plugs and reset gaps to 0.030 in. (average breakdown pressure was now 117 psi). One plug was replaced.
4 The carburetor was cleaned and reassembled with new gaskets and set to manufacturer's specifications. No noticeable defects or maladjustments were detected while cleaning the carburetor; however, data given in Table III show that air/fuel ratio was on the lean side before tune-up.

After the tune-up had been completed, another set of samples was taken to complete the test. Comparative data, giving analytical results before and after tune-up, given in Table III, show that significant reductions in particulate emissions were achieved by engine tune-up. Thus, it is obvious that maintenance practices exert a large influence on the emission of both hydrocarbon vapor and particulates. The maladjustments present in the engine caused a considerable increase in vapor emission under idling conditions, and an increase in particulate emission under all operating conditions. There was no satisfactory way to simulate deceleration on the chassis dynamometer, but vapor emission would probably be increased in this instance as well as under idling conditions. None of the maladjustments present before the tune-up would be considered serious; to the average motorist, the engine was performing satisfactorily.

Series III

A 1956 Oldsmobile V-8 engine, having a 9.25 to one compression ratio, was the basic engine used in this series of tests. This engine was used in the "fabrication" of two other engines by replacing the pistons with special types of pistons, to convert the engine into one having an 8.5 to one compression ratio and another having a 10.5 to one compression ratio. The three engines were each subjected to a series of tests, as outlined below in the order in which they were performed:

1 "Clean" Engine: The engine was given a complete overhaul followed by a shakedown run over a period of 8–10 hr (equivalent to about 400 to 500 mi) in order to make certain that all engine components were functioning properly and to seat the rings. For the tests at 8.5 to one and 10.5 to one compression ratios, the special pistons were substituted during the overhauls. A complete set of duplicate samples was taken from the engine under five operating conditions.
2 "Dirty" Engine: The engine was subjected to a run at a simulated cruising speed of 50 mph for a period of 60 hr (total trip = 3000 mi) to build up engine deposits. A set of duplicate samples was then taken.
3 "Leaky Rings" Engine: The pistons were removed and the ring gaps opened (filed) to 0.060 in. so as to simulate worn rings which would increase oil consumption. The engine was reassembled without disturbing the combustion chamber deposits and a third set of duplicate samples taken.
4 Blowby Samples: Particulate samples were taken of the blowby gases, which are discharged through the breather pipe of the "leaky ring" engines. All other openings to the crankcase were plugged so as to divert all the blowby through the breather pipe. The particulate sampling was performed by means of a high volume sampler controlled by a variable transformer.

Total hydrocarbon emissions in the exhaust gases are given in Table IV. Total particulate and organic (benzene-soluble) particulate emissions are given in Table V. The quantities of free acidity, aliphatic olefins, and carbonyl compounds (aldehydes and ketones) emitted as benzene-soluble particulates are expressed in Table VI. A brief summary of the effects of engine variables on both particulate and gas phase emissions appears in Table VII. Data obtained from the "clean," "dirty," and "leaky" engines indicate that somewhat more conclusive results might have been obtained had the 3000 mi runs, which were used to build up engine deposits, been approximately 10,000 mi, in which case more significance could be attached to results obtained from both the "dirty" and "leaky" engines.

This series of tests was conducted to see if consistent trends in exhaust emission could be established as a function of compression ratio. However, an examination of the data indicated that lowest over-all emission of both vapor and particulates occurred with the original compression ratio. Any deviation from the original design figure, either an increase or decrease, resulted in increasing the exhaust emission. Therefore, it was concluded that compression ratio changes could not be studied without redesigning the entire engine to provide optimum operation at each compression ratio. Some of the factors which probably should be considered in such a redesign would include geometry of the combustion chamber,

Table IV—Hydrocarbon Content of Exhaust Gases

Data from Series III Engine Tests

Engine Description: Compression Ratio	Engine Description: Condition of Engine	Idle: Hexane, Ppm	Idle: Hexane per Min, Mg	Idle: Flow Rate, Cfm (60°F)	30 Mph Cruise: Hexane, Ppm	30 Mph Cruise: Hexane per Min, Mg	30 Mph Cruise: Flow Rate, Cfm (60°F)	50 Mph Cruise: Hexane, Ppm	50 Mph Cruise: Hexane per Min, Mg	50 Mph Cruise: Flow Rate, Cfm (60°F)
8.5 to 1	"Clean"	340	430	12	92	360	38	[a]	[a]	72
8.5 to 1	"Dirty"	740	1100	15	240	850	35	200	1400	69
8.5 to 1	"Leaky Rings"	670	1100	16	250	930	36	130	880	70
9.25 to 1	"Clean"	140	220	16	91	420	46	[a]	[a]	75
9.25 to 1	"Dirty"	230	330	13	110	420	38	[a]	[a]	68
9.25 to 1	"Leaky Rings"	200	270	13	120	450	36	97	690	71
10.5 to 1	"Clean"	600	920	15	160	580	36	150	1100	72
10.5 to 1	"Dirty"	2200	2400	18	190	690	35	170	1300	73
10.5 to 1	"Leaky Rings"	1100	1800	17	250	880	34	190	1400	68

Engine Description: Compression Ratio	Engine Description: Condition of Engine	30 Mph Acceleration: Hexane, Ppm	30 Mph Acceleration: Hexane per Min, Mg	30 Mph Acceleration: Flow Rate, Cfm (60°F)	30 Mph Deceleration: Hexane, Ppm	30 Mph Deceleration: Hexane per Min, Mg	30 Mph Deceleration: Flow Rate, Cfm (60°F)
8.5 to 1	"Clean"	190	4,400	219	4900	11,000	23
8.5 to 1	"Dirty"	490	12,000	242	7700	20,000	25
8.5 to 1	"Leaky Rings"	430	11,000	237	5100	14,000	27
9.25 to 1	"Clean"	180	5,100	276	2100	8,300	37
9.25 to 1	"Dirty"	280	6,700	234	[b]	[b]	34
9.25 to 1	"Leaky Rings"	200	5,400	238	2900	9,200	31
10.5 to 1	"Clean"	270	6,600	238	8300	20,000	24
10.5 to 1	"Dirty"	370	9,200	246	8800	28,000	31
10.5 to 1	"Leaky Rings"	420	12,000	248	7300	24,000	32

[a] Due to lack of sensitivity of I. R. method, there were times that a measurable absorption was not obtained. The hydrocarbon emission in these cases may be anywhere from 0 to 800 mg/min or 0 to 100 ppm.
[b] No gas sample obtained.

valve size and timing, ignition timing, cooling, carburetion, and geometrical design of intake and exhaust manifolds. The data obtained in these tests indicate that many factors in engine design influence exhaust emissions, and that these relationships are interrelated. Any attempt to generalize on the effects of engine design changes on exhaust emissions may lead to erroneous conclusions.

Molecular weight determinations were made on the original motor oil and five samples of the nonvolatile organic (benzene-soluble) particulate taken from the 10.5 to one compression engine. The "average" molecular weights found are listed below:

Motor Oil, M. W. = 476
Idling Sample, M. W. = 554
30 mph Cruising Sample, M. W. = 538
50 mph Cruising Sample, M. W. = 596
30 mph Acceleration Sample, M. W. = 449
30 mph Deceleration Sample, M. W. = 472

The molecular weight of the deceleration sample was the same as that for the original motor oil. The two were also alike in visual appearance and showed identical infrared spectra. On another test, the motor oil contained a large unidentified absorption band at around nine microns which was attributed to an additive, and the same absorption appeared in the organic fraction of the particulate sample taken under deceleration. Therefore, it was established that the organic fraction of the particulate, under deceleration conditions, was essentially unchanged motor oil that apparently was carried up around the rings on the compression stroke as an oil mist, and was then carried out the exhaust.

With operating conditions other than deceleration, the organic fraction was different in appearance and chemical characteristics from the original motor oil. Apparently, under the more rigorous conditions in the combustion zone, chemical reactions occurred to change the oil into other reaction products somewhat similar in nature. In general, these reactions tended to change the olefin content, acidity, and carbonyl content, but in a manner which did not show consistent trends when compared to the severity of the operating conditions.

Table V—Total Particulate and Organic Particulate Emissions

Data from Series III Engine Tests

Engine Description: Compression Ratio	Engine Description: Condition of Engine	Idle: Part. per Min, Mg	Idle: Org. per Min, Mg	30 Mph Cruise: Part. per Min, Mg	30 Mph Cruise: Org. per Min, Mg	50 Mph Cruise: Part. per Min, Mg	50 Mph Cruise: Org. per Min, Mg	30 Mph Acceleration: Part. per Min, Mg	30 Mph Acceleration: Org. per Min, Mg	30 Mph Deceleration: Part. per Min, Mg	30 Mph Deceleration: Org. per Min, Mg
8.5 to 1	"Clean"	50	6.3	31	1.1	89	0.51	198	0.88	121	100
8.5 to 1	"Dirty"	71	11	30	6.5	50	0.70	139	1.6	143	120
8.5 to 1	"Leaky Rings"	79	12	34	13	60	0.95	148	1.4	151	130
9.25 to 1	"Clean"	8.3	0.77	39	1.1	70	0.37	107	0.78	175	160
9.25 to 1	"Dirty"	9.3	0.75	39	0.61	96	0.32	201	0.71	294	270
9.25 to 1	"Leaky Rings"	9.4	0.96	40	0.81	76	0.48	117	1.7	161	140
10.5 to 1	"Clean"	64	11	32	1.9	64	1.7	201	2.6	210	200
10.5 to 1	"Dirty"	79	13	28	2.9	61	1.0	322	1.9	132	110
10.5 to 1	"Leaky Rings"	89	14	29	1.7	53	0.73	357	1.3	158	130

Note: All figures are milligrams per minute of operating time, for conditions specified. For exhaust flow rates, see Table IV.

Table VI—Chemical Analysis of Organic Fraction of Exhaust Particulates

Data from Series III Engine Tests

Engine Description		Idle			30 Mph Cruise			50 Mph Cruise		
Compression Ratio	Condition of Engine	Free Acidity	Olefins	Carbonyl	Free Acidity	Olefins	Carbonyl	Free Acidity	Olefins	Carbonyl
8.5 to 1	"Clean"	10	21	1.5	1.0	2.4	2.2	0.4	2.7	3.2
8.5 to 1	"Dirty"	14	30	1.9	0.9	6.9	1.5	0.9	3.2	4.1
8.5 to 1	"Leaky Rings"	23	40	3.2	1.6	12	1.1	0.9	2.2	2.3
9.25 to 1	"Clean"	0.4	1.8	0.83	1.4	2.0	1.4	Nil	0.88	7.6
9.25 to 1	"Dirty"	0.3	1.2	1.8	0.2	1.7	2.6	Nil	1.9	4.4
9.25 to 1	"Leaky Rings"	0.6	1.7	0.07	0.3	1.1	2.9	Nil	1.2	1.7
10.5 to 1	"Clean"	16	34	2.3	1.1	3.2	2.2	1.6	5.9	3.8
10.5 to 1	"Dirty"	21	38	2.4	1.0	2.4	3.3	0.4	3.5	3.8
10.5 to 1	"Leaky Rings"	17	45	1.3	0.5	3.2	0.42	0.6	2.5	1.4

Engine Description		30 Mph Acceleration			30 Mph Deceleration		
Compression Ratio	Condition of Engine	Free Acidity	Olefins	Carbonyl	Free Acidity	Olefins	Carbonyl
8.5 to 1	"Clean"	0.8	4.2	6.5	2.2	63	2.5
8.5 to 1	"Dirty"	0.7	8.1	11	4.5	70	2.6
8.5 to 1	"Leaky Rings"	0.4	4.2	1.9	3.5	80	0.67
9.25 to 1	"Clean"	Nil	1.4	7.5	2.8	81	2.7
9.25 to 1	"Dirty"	Nil	2.6	9.1	3.3	140	0.17
9.25 to 1	"Leaky Rings"	Nil	3.8	8.7	2.0	91	4.2
10.5 to 1	"Clean"	Nil	3.3	6.2	3.5	120	3.0
10.5 to 1	"Dirty"	Nil	3.8	8.7	4.5	68	3.0
10.5 to 1	"Leaky Rings"	0.6	5.0	4.0	5.0	88	2.8

Note: All figures are micromoles per minute of operating time, for conditions specified.

The molecular weight data may give a clue to this anomaly. The olefin formation would indicate that cracking reactions were occurring, possibly in combination with other types of reactions. Yet, the average molecular weight showed a tendency to increase rather than decrease, compared to the unreacted material found in the motor oil and deceleration samples. This would indicate that some of the reaction products were lower molecular weight compounds which were distilled out of the oil fraction at the high temperatures found in the combustion zone. Some flash evaporation of the lower molecular weight constituents of the oil also likely occurred, accounting for the increase in average molecular weight. The slight decrease in molecular weight under acceleration conditions provides additional evidence of this mechanism; the high temperature would initiate cracking and possibly other reactions, but due to the extremely high exhaust flow rate, the exhaust passed out of the combustion zone before flash evaporation could occur.

A consideration of the factors affecting these reaction mechanisms illustrates the complexity of the over-all situation. Cracking and other chemical reactions are influenced by pressure, temperature, residence time, catalytic effects of cylinder walls and soot particles, and possibly other variables. With each change in engine speed or load, or both, all of these variables change in a complicated, interrelated manner. Thus, as with the effects of varying engine design parameters as discussed previously, it is difficult or impossible to generalize on the effects of engine operating variables on the chemical reactions that occur in the combustion zone to produce the nonvolatile organic constituents found in the exhaust particulates.

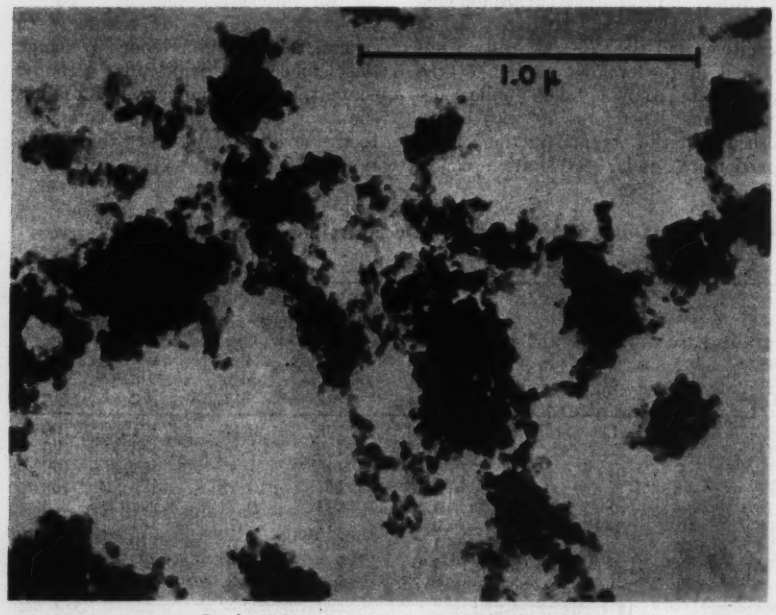

Fig. 1. Exhaust particulates—engine idling.

The emission of total particulate and organic particulate matter in the blowby gases (Table VIII) is quite significant in that the blowby particulate is nearly all organic in composition; in fact, the emission of particulate organics is greater in the blowby than in the engine exhaust. The infrared spectra and the low levels of olefins, carbonyl, and free acidity in the organic phase of the blowby particulate prove that it is composed almost entirely of unchanged lubricating oil. It is emitted as an aerosol consisting of motor oil with small amounts of gasoline dissolved in the droplets. Unfortunately, blowby samples were not taken before the ring gaps were enlarged; however, blowby flow measurements taken before and after enlarging the ring gaps demonstrated that blowby flow rates were doubled with the 9.25 to one compression ratio engine and tripled with the other two compression ratios. One might assume that the particulate emissions in the blowby were affected in a somewhat similar manner. Typical blowby flow

Table VII—Summary of Effects of Engine Variables on Automobile Exhaust Emissions

Data from Series III Engine Tests

Engine Variable	Effect on Particulate Emissions	Effect on Vapor Phase Emissions
Compression Ratio Change	Total: Idling—greatly increased when deviated from design figure Other operating conditions—inconclusive Organic content, Free acidity, Olefin formation: Increased when deviated from design figure Carbonyl: Idling—increased when deviated from design figure Other operating conditions—inconclusive	Hydrocarbons: Increased when deviated from design figure
"Clean" vs "Dirty" Engine	Total: Inconclusive Organic content: Inconclusive Acidity: Inconclusive Olefins, Carbonyl: Increased with "dirty" engine	Hydrocarbons: Definite increase with "dirty" engine
"Clean" vs "Leaky" Engine	Total, Organic content: Slight increase with "leaky" engine Acidity: Inconclusive Olefins: Slight increase with "leaky" engine Carbonyl: Definite decrease with "leaky" engine	Hydrocarbons: Definite increase with "leaky" engine

"Clean" engine—tests conducted as soon as engine was assembled following short run to seat rings. Oil consumption usually was 0–1 qt per 1000 mi.
"Dirty" engine—tests conducted following "clean" engine tests plus an additional run of 3000 mi to build up combustion chamber deposits. Oil consumption usually was 0–1 qt per 1000 mi.
"Leaky" engine—Ring gaps filed to leave 0.060 in. opening when reassembled. Oil consumption usually was 1–2 qt per 1000 mi.

rates (9.25 to one compression engine, ring gaps) were 0.64 cfm for idle, 0.78 cfm for 30 mph cruising, 0.92 cfm for 50 mph cruising, and 3.6 cfm for 30 mph acceleration.

Blowby flow rates are much lower than exhaust flow rates; however, the higher concentration of both vapor and particulates in the blowby indicates that the blowby emissions are a substantial fraction of the exhaust emissions. An accurate estimate of total blowby emissions would be difficult to obtain since this depends on engine condition and maintenance practices, probably to a greater extent than do exhaust emissions.

In order to merely indicate the order of magnitude of gaseous blowby emissions, grab samples of blowby were collected from three automobiles under idling conditions, and the gaseous hydrocarbon content determined. The range was from approximately 70–540 mg (hexane equivalent) per min of operating time. Thus, as a very rough estimate, it appears that gaseous emission in the blowby is equal to perhaps one-third to one-half of the gaseous emission in the exhaust. More recently this has been confirmed by other investigators,[4] and plans are being made to feed blowby gases back into the carburetor air intake, as a means of reducing this source of hydrocarbon vapor emission.

Table VIII—Particulate Emissions in Crankcase Blowby

Engine Description: Compression Ratio	Engine Description: Condition of Engine	Idle: Part. per Min, Mg	Idle: Org. per Min, Mg	Idle: Flow Rate, Cfm[a]	30 Mph Cruise: Part. per Min, Mg	30 Mph Cruise: Org. per Min, Mg	30 Mph Cruise: Flow Rate, Cfm[a]
8.5 to 1	"Leaky Rings"	5.9	5.3	0.75	21	21	0.85
9.25 to 1	"Leaky Rings"	5.6	5.3	0.64	17	16	0.78
10.5 to 1	"Leaky Rings"	[b]	[b]	[b]	23	23	0.82

Engine Description: Compression Ratio	Engine Description: Condition of Engine	50 Mph Cruise: Part. per Min, Mg	50 Mph Cruise: Org. per Min, Mg	50 Mph Cruise: Flow Rate, Cfm[a]	30 Mph Acceleration: Part. per Min, Mg	30 Mph Acceleration: Org. per Min, Mg	30 Mph Acceleration: Flow Rate, Cfm[a]
8.5 to 1	"Leaky Rings"	34	34	1.08	57	56	3.17
9.25 to 1	"Leaky Rings"	21	20	0.92	103	100	3.58
10.5 to 1	"Leaky Rings"	40	40	1.30	232	231	3.99

[a] Flow rates corrected to 60°F and 14.7 psia.
[b] Sample was not obtained.

Physical Characteristics

An extensive study of the physical characteristics of exhaust particulates was not conducted, since this had been investigated previously.[3] However, electron microscope photographs were obtained of a few representative samples of exhaust particulates, in order to illustrate the great variety of shapes and sizes which can occur.

Samples were obtained with a thermal precipitator, depositing the particles on a collodion-coated perforated brass screen which was mounted on a glass microscope slide with collodion. The exhaust was withdrawn from the exhaust line a short distance from the manifold, and was immediately diluted with two to three volumes of dry air to prevent condensation of water in the thermal precipitator. After collection, the brass screen was lifted from the slide and mounted for use in the electron microscope.

Figure 1 shows a photograph of exhaust particulates collected from a 1954 Plymouth engine, under idling conditions. The sample consisted of agglomerates of smaller particles. By shadowing techniques, it was determined that the agglomerates were irregular in thickness but tended to be rather flat, due possibly to mechanical flattening at the time of impaction on the slide.

Figure 2 shows a photograph of exhaust particulates collected under 30 mph cruise conditions, using the same 1954 Plymouth engine. The individual particles were much larger, and the tendency to agglomeration was much less pronounced than with the idling sample. By shadowing techniques, it was established that the individual particles were approximately spherical in shape.

Summary and Conclusions

Automobile exhaust particulates amount to approximately 5% by weight of the amount of gaseous hydrocarbon emission, and consist of lead compounds, carbon particles, motor oil, and nonvolatile reaction products formed in the combustion zone from motor oil. These reactions involve the formation of free acidity, high molecular weight olefins, and carbonyl compounds. Quantitative estimates of the effects of engine design variables and changes in operating condition on these chemical reactions cannot be made because of the very complex relationships involved.

Particulates in the blowby are composed almost entirely of unchanged

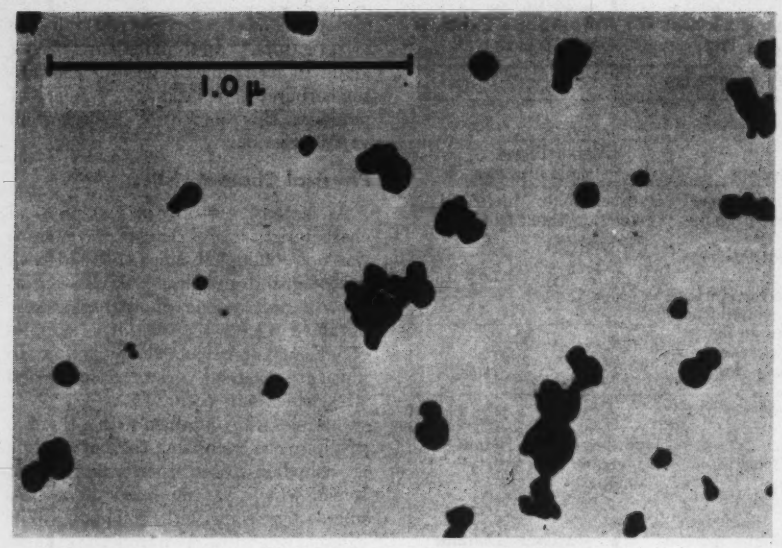

Fig. 2. Exhaust particulates—30 mph cruise.

lubricating oil. As a very rough approximation only, the amount of material emitted in the blowby is perhaps one-third to one-half the amount emitted in the exhaust; the same approximate ratio applies to either particulate emission or gaseous hydrocarbon emission. Blowby emissions are influenced by mechanical condition of the engine, probably to a greater extent than exhaust emissions.

The total amount of exhaust particulate emitted from automobiles is much less than the amount of hydrocarbon vapor emitted, and therefore from an over-all pollution standpoint is less important as a primary pollutant. The extent to which the particulates may influence atmospheric reactions is not known, but the physical and chemical nature of the particulates would indicate that important effects might occur. The catalytic effects of finely-divided carbon are well known, and the nonvolatile olefinic, acidic, and carbonyl compounds associated with the carbon might be expected to be quite reactive. This suggests the possibility that the particulates might influence the course of gas-phase atmospheric reactions through catalytic or other effects. Similar effects are known in other situations where particles containing a reactive substance act to initiate a chemical reaction involving gaseous compounds, by providing reaction sites where gases can be adsorbed and held in close proximity to other reactants. This would appear to be a potentially fruitful area for further investigation.

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An INSPECTION METHOD for Automobile Hydrocarbon Emission*

ROBERT L. CHAPMAN, Infrared Supervisor, Application Engineering, Scientific and Process Instruments Division, Beckman Instruments, Inc., Fullerton, Calif.

In June of 1959, the Governor of California took the first step toward the formulation of unprecedented legislation to control the emission of specific air contaminants from motor vehicle exhaust. Years of endeavor by scientists and public officials preceded this act, but in order to implement it, much more work lay ahead. Not the least of this involved the development of practical, simple methods for the analysis of auto exhaust, that may be used by the law enforcing agencies.

Past Legislation Ineffective

Prior to 1959 several states had legislation on their books outlawing excessive emission of "smoke" from motor vehicles. A few states have attempted to enforce such laws in densely populated areas. Cincinnati, Ohio, for example, has for several years included a visual check on smoke emission as part of its vehicle inspection routine. Recently, California has increased its vigilance against motor vehicles emitting excessive smoke. The patrolmen are armed with Ringelman type comparison charts and instructed to disallow densities higher than 40%. Such limitations will undoubtedly improve the esthetic qualities of auto exhaust, but may have little or no affect on its smog producing capacity, since the components of exhaust that produce smog are invisible.

Future laws will set limits on the emission of the invisible smog producing components. However, for such laws to be written definitively and enforced effectively, the nature of the offensive components must be determined, methods for their detection and measurement must be developed, and effective means for their reduction in auto exhaust must be provided.

Official Statement of the Problem

The first question is, "What are the specific offensive components?" It was to arrive at an official statement of the answer that Governor Brown of California took his first step last June. He signed a bill requiring the State Board of Public Health to establish standards for exhaust emission from motor vehicles. These standards are not easily set, however. Early in the last decade, Dr. Haagen-Smit of the California Institute of Technology demonstrated that a wide variety of organic compounds have ozone-forming capacity when nitrogen dioxide is present and the mixture is irradiated with sunlight.[1]

The chemistry involved in this conversion and the subsequent production of aerosols and eye irritants is extremely complicated and has not been fully defined. It has been clearly demonstrated, however, that the unburned and cracked fuels emitted in auto exhaust play a major role and that if they are eliminated the smog producing capacity of the exhaust is curtailed. Therefore, the first officially recommended standard for auto exhaust set a limit on total hydrocarbon content.

Controlling the Problem

The problem of controlling the hydrocarbon emission has not been completely solved, although many devices have been developed and it appears that we are not far from a practical solution.

Evaluating the Control

This leaves the problem of a practical method for the detection and measurement of the hydrocarbons. Numerous laboratory methods have been developed during the past eight years for the identification and measurement of airborne contaminants including hydrocarbons. These include methods of concentration with subsequent chemical analysis, direct spectroscopic methods, and gas chromatography. These methods, combined, have been extremely valuable in understanding the complex chemistry of photochemical smog. They have also been applied to the identification of a great many of the components in raw auto exhaust and in studying the interrelation of fuels, engine variables, and exhaust composition. These instruments are expensive, however, and some of them require personnel with special training. Relatively inexpensive nondispersive infrared analyzers have been used successfully for specific auto exhaust studies requiring only moderate sensitivity and very rapid, continuous response, such as field surveys and study of transient effects.[2] These instruments lack the sensitivity required for the evaluation and inspection of highly efficient hydrocarbon removal devices. Furthermore, their relative sensitivities to various hydrocarbons are not identical or completely reproducible from unit to unit.[3] Until very recently, therefore, there remained a need for a simple, inexpensive, and extremely sensitive method by which to sense all hydrocarbons on an equal basis, discriminate against other major components of auto exhaust, and provide an instantaneous answer. The flame ionization detection method, recently perfected for gas chromatography, appears to fill this need.

The hydrogen flame detector operates on the principle of combustion ionization. The exact nature of the phenomenon is not completely proved as yet, but it appears that during combustion hydrocarbons are broken down into smaller particles, a few of which are subsequently ionized. These ions are accelerated toward a collector by an electrical field, and the resulting current is measured. In the chromatograph application, a fraction of the helium carrier gas is mixed in constant proportion with hydrogen and passed through a fine jet. Air is supplied through a tube coaxial with the jet. The jet diameter and the ratio of gas flows are selected to produce a minute flame whose average temperature is below that which will produce ions directly. A likely cause of the ionization of the hydrocarbons is the excess energy released during the oxidation of carbon to carbon dioxide. This release of energy may produce local hot spots within the flame which are at sufficiently high temperature to cause ionization. This theory, when fully developed,

* Presented at the 53rd Annual Meeting of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

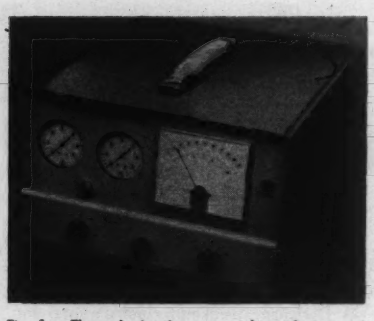

Fig. 1. Flame ionization auto exhaust instrument

explains why only the hydrocarbons are ionized.[3] The ion current is proportional to the rate of introduction of sample to the flame; therefore, a change in either flow rates or hydrocarbon concentration will affect it. If the flow rates are held constant, however, the ion current is directly proportional to the carbon concentration in the carrier gas. It has been demonstrated that approximately one carbon atom in 500,000 leads to the production of an ion pair and that sensitivities of 1 ppb in the carrier gas can be obtained.[4]

An Inspection Method

In the application of this method to the auto exhaust problem, no chromatograph column is involved, so there is no ready-made source of helium. Therefore, a tank mixture of the proper proportions of helium and hydrogen is supplied. The exhaust sample is blended continuously with the helium-hydrogen mixture and introduced to the base of the jet. Pure cylinder air is supplied in the annular space around the jet, as before. The flows are controlled by pressure regulators and capillaries so that adjustment is extremely simple. A small pump is enclosed in the instrument and serves to draw the exhaust sample from the automobile tail pipe. Figure 1 is a photograph of the completed instrument. In use, the gas cylinders are attached to rear connections. The instrument operates on normal ac power or on a battery through an accessory converter. The gages indicate the pressure of fuel and sample. The instrument is standardized by zeroing with no sample and adjusting one upscale range with a known sample.

Table I—Observed Sensitivities and Calculated Carbon Atom Sensitivities for Various Compounds

Compound	Observed Sensitivity	Calculated Carbon Atom Sensitivity
C_5H_{12}	0.85	0.17
C_6H_{14}	1.06	0.17
C_7H_{16}	1.24	0.18
C_6H_6	1.18	0.20
C_7H_8	1.32	0.19
C_2H_5OH	0.309	0.15
C_3H_7OH	0.476	0.16
C_4H_9OH	0.655	0.16
$C_2H_5-O-\overset{O}{\overset{\|}{C}}-CH_3$	0.442	0.11
$C_3H_7-O-\overset{O}{\overset{\|}{C}}-CH_3$	0.645	0.13
$C_4H_9-O-\overset{O}{\overset{\|}{C}}-CH_3$	0.855	0.14
CH_2Cl	0.149	0.15
CCl_4	0.077	0.08
C_2Cl_4	0.398	0.20

Full scale ranges of 100, 300, 1000, and 10,000 ppm may be selected by means of the attenuator. The instrument is linear to better than 1% over these ranges. Higher or lower ranges with equal linearity can be obtained by substituting capillaries inside the instrument. Response speed is in the order of a few seconds. The relative sensitivities to various hydrocarbons is essentially equal on a mole percent carbon basis. Oxygenated compounds give slightly lower relative signals. The instrument is insensitive to water vapor, carbon dioxide, carbon monoxide, inorganics, and inert gases. Table I represents observed relative sensitivities for several types of compounds, and the calculated relative carbon atom sensitivity for each.

Possibilities and Limitations

This instrument appears to satisfy the current requirements for hydrocarbon removal device inspection, on the basis of total hydrocarbon residue. It has been shown theoretically that olefinic hydrocarbons are much more potent smog producers than paraffinic compounds,[5] and current development of hydrocarbon eliminators is aimed at olefins specifically. If it is eventually proved conclusively that paraffinic hydrocarbons contribute essentially nothing to smog formation, the legislation may be changed to limit only the olefins. The ionization analyzer, as it stands, is not suitable for such a determination. It could be used as a detector, however, in conjunction with a simple stripper column to separate the components. Time delay would be increased and operation would be cyclic rather than continuous.

Conclusions

At the present time we are very close to being able to draft logical, effective legislation to control automobile generated smog. We have physical means of controlling the emission of the smog producing components, and we now have the means of inspecting these control devices.

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Season's Greetings from APCA

A Multipurpose FLARE STACK for Control of Chemical PROCESS WASTES*

JOSEPH F. MELLOR, Jr., Warners Plant, American Cyanamid Co.

Experience in the manufacture of an organic thiophosphate compound demonstrated a need for the control of localized air pollution apparently caused by a vacuum operation employing steam ejectors. The odors created by the vacuum system were offensive and the volatile components released from the liquid effluent were suspected as a local source of in-plant eye irritations. The remedy to be applied was not immediately apparent and it was learned by literature review that relatively little attention had been given to the air pollution problems sometimes associated with the vacuum jet operations of the chemical industry.

Magruder[1] indicated that vacuum jet effluents were controlled in the oil industry's program to control air pollution in the Los Angeles area. The method was not delineated, however. Kanter and Deckert,[2] cited in the same review, were more specific as to method and reported on a technique wherein the vapors from the vacuum jets were condensed. This allowed for the collection of hydrocarbons and water. The hydrocarbons were decanted and incinerated. Ells[3] has reported on the capture of the sump gases from a petroleum refining vacuum process and of their incineration in the furnace of the processing unit. A literature record of this technique for use in the chemical industry could not be found.

Incineration appeared to be a desirable technique and the method reported by Garrett[4] elicited considerable interest. His technique used incineration in a chemical manufacturing process for the control of entrained organics from waste waters. The system he described also disposed of waste organic tars and soot. These were slurried with fuel oil and incinerated. The significant benefit of this technique, however, was the destruction of the volatiles in the organic-containing waste water stream. This was accomplished by steam stripping these liquid wastes and incinerating the volatilized organic component. It appeared that some features of this system could be adapted to a batch type operation.

Vacuum in our process was achieved by the steam jet ejector. Figure 1 illustrates a typical ejector which consists of a combined steam motivated venturi and diffuser. High velocity steam through the nozzle causes an entrainment of the gases surrounding it. Thus it draws vacuum in the chamber and in the connecting piping of the chemical process.

The degree of vacuum achieved by the ejector may be considered to be a function of the steam pressure employed and the number and arrangement of the stages used. To economically increase the degree of vacuum attained the barometric condenser is employed. It is a scrubber into which cooling water is discharged to condense the steam and vapors drawn from the process. Thus by cooling the entrained vapors the volume of gas to be handled by added stages is reduced. This also causes reduced steam usage for the succeeding stages. The water in the barometric drainpipe entrains condensable and noncondensable volatiles which are vented at the atmosphere at the hotwell. The barometric condenser is usually located 34 ft above grade so as to prevent loss of vacuum in the system.

It is in the venting of these vapors at the hotwell that the potential air pollution problem may develop. The degree and significance of air pollution from this source would be dependent upon:

1 The physical properties of the reactants entrained in the hotwell vent gases.
2 The physiological nature of the noncondensables released to the atmosphere.
3 The temperature of the water in the hotwell.
4 The efficiency of the intervening knock-out condensers which return condensate to the process.

Odor Control

The intermittent evolution of hydrogen sulfide from our basic batch reaction necessitated the construction of a flare stack to dispose of this gas in lieu of scrubbing or recovery. Investigation was made to determine the feasibility of using this flare stack to incinerate the volatiles entrained by the vacuum system.

Investigation disclosed that the odorous hotwell gases were in the combustible range and it was decided to vent the hotwell through the flare stack. As noted by the increased size of the flame combustion was readily effected. An additional hotwell in the same process was similarly vented into the flare stack with an increase in the size of the flame. Thus the former discharge of the odorous vapors at ground level was discontinued and an improved olfactory effect was immediately apparent. Figure 2 illustrates the general arrangement of the system.

Effect on Waste Water

It was observed that by careful regulation of the water flow to the barometric condenser and by adjusting it down to a level compatible with good operation a secondary beneficial effect was obtained. The odor qualities of liquid effluent from the hotwells was considerably improved. The hotwells were in effect serving a multipurpose; they acted not only as a seal for the barometric legs but the atmospheric exhausts of the second stage jets of the vacuum system provided a good waste heat supply and caused entrained volatiles to be stripped from the barometric waters. The hotwell, a tool of convenience, was now transformed to a process tool.

In noting the beneficial effect on the effluent from the hotwells a still further use was suggested. In many organic chemical processes water is formed as a side product of reaction. Many processes require washing of the organic product with fresh water. These waters

* Presented at the 53rd Annual Meeting of APCA, May 22–26, 1960, Netherland-Hilton Hotel, Cincinnati, Ohio.

are usually highly contaminated and contribute to odor generation in the effluent stream. These contaminants also add to the treatment required for this type of effluent. By diverting these contaminated process waters into a collection tank they can be pumped into the hotwell at a slow rate and, given sufficient residence time, the volatiles can be flashed off and vented to the flare.

Smokeless Flame

Other beneficial effects of the system from an air pollution abatement viewpoint were noted. The relatively smokeless quality of the burning flame was a distinct advantage. The steam from the atmospheric exhaust of the second stage jets contributed to the attainment of this smokeless burning.

Fire Prevention

The tie-in of process vents containing highly flammable vapors obviously required adequate fire control measures. These features were well considered and water seal pots were provided as flashback arresters. Actually each vent leading to the flare stack is provided with a 2 in. water seal. A continuous water supply to the flashback arresters is maintained to prevent the accumulation of flammable volatiles which condense in the water seal pot. The overflow water carrying the volatiles is diverted to the hotwell and they are flashed off to the flare.

Economics of Method

On an economic basis the system described has proved to be quite satisfactory. The flare has a continuous pilot ignited by liquid propane gas which is delivered to the plant by truck. Since hydrogen sulfide is generated continuously, once the batch reaction has been started, its flame is self-perpetuating. This situation obviated the need for an enriching gas fuel feed to the flare, other than that used by the pilot itself. In the accounting records propane costs are considered as a stores and materials item and it is not cost itemized against the product. Prorating the cost of propane used on this flare for over 121 days' operation, it was learned the total fuel cost was $390 or $3.22 per day.

Extent of Application

The system described has been successfully applied to five 500-gal glass-lined Pfaudler reactors. Two of these reactors vent hydrogen sulfide to the 4 in. John Zink flare directly through double seal pots as described.

The remaining three vacuum reactors are vented to the flare through the hotwells and associated seal pots. These latter three reactors operate at a vacuum of 15 mm Hg and with an adequate sizing of the hotwell vents no difficulty is experienced with excessive back pressures on the system. Further, there is no difficulty as to the sequence of operation of these five reactor vessels. All may operate simultaneously or only one can operate without interfering with the other reactors. All combinations have been employed with equal effectiveness.

The system described has operated satisfactorily for approximately one year. It has resulted in a marked improvement in the area and it has also caused a significant reduction in the

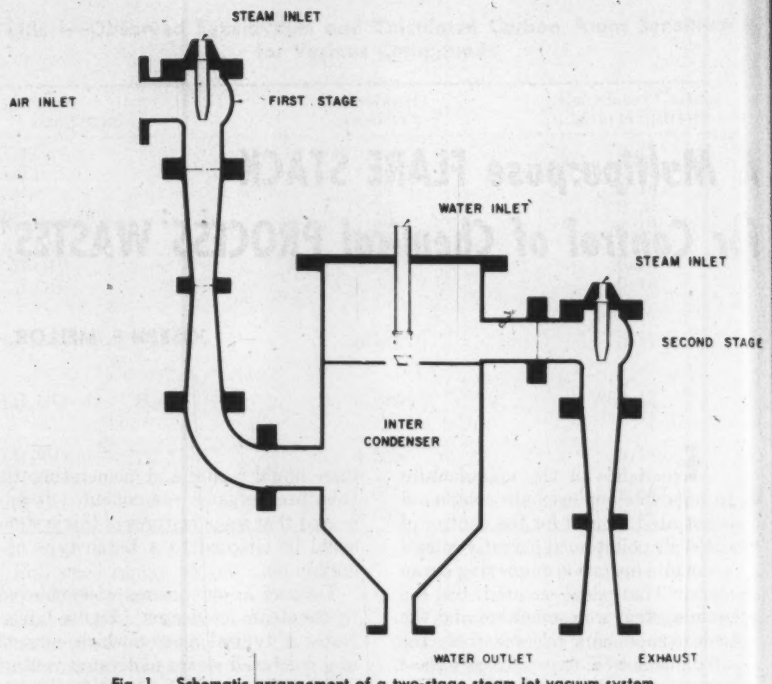

Fig. 1. Schematic arrangement of a two-stage steam jet vacuum system.

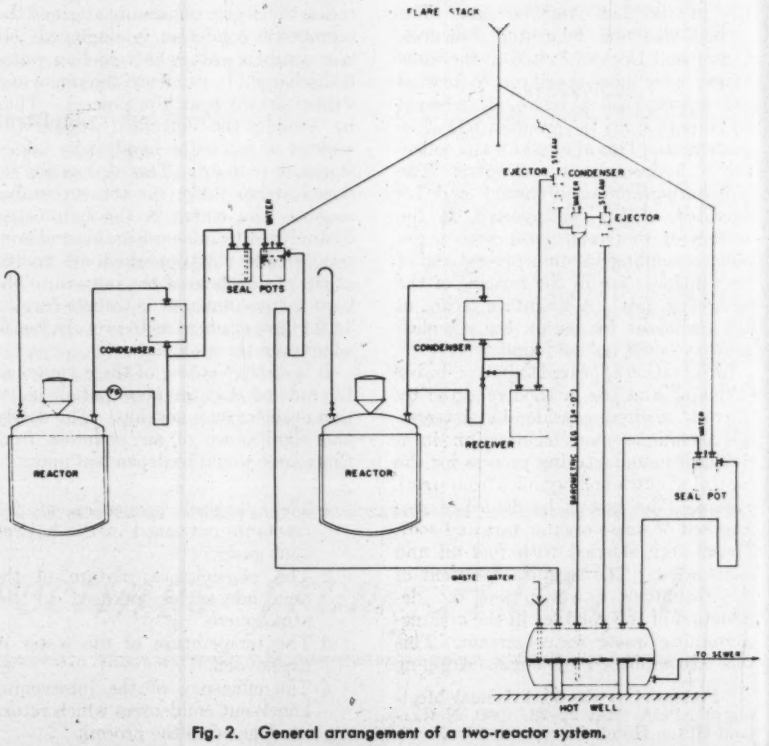

Fig. 2. General arrangement of a two-reactor system.

organic loading of the effluent stream. Unlike many air pollution control devices this system not only significantly reduces the air pollution potential it also reduces the loading to the liquid effluent system. It requires a small capital investment and has minimal operating cost. In this instance, the sulfur dioxide loading is not excessive and, with the thermal rise given to this gas by the hot flame at the flare tip, it is readily dispersed into the atmosphere without hazard or annoyance. The uniqueness of the system, however, lies in the fact that this air pollution control method aids in the reduction of a potential stream pollution problem by incinerating a significant portion of the organic component of the waste water system. It is a system that operates satisfactorily, destroys odor and diminishes the loading of the waste water stream. It is also a system which, with slight tailoring, may be capable of use wherever volatile combustible organics are vented through steam ejector systems.

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AIR QUALITY STANDARDS FOR CALIFORNIA

(*Continued from p. 455*)

which there is complete safety and above which there is certain illness or death. Obviously, they can sometimes be exceeded without injury to an individual. The air standards that have been adopted will have to be used intelligently with the appreciation of their limitations as well as their application.

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AIR POLLUTANTS IN MEXICO CITY

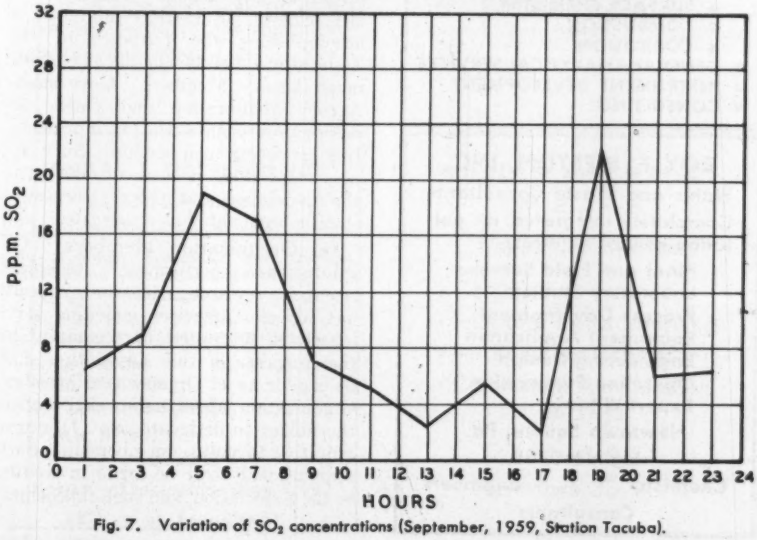

Fig. 7. Variation of SO_2 concentrations (September, 1959, Station Tacuba).

BIOLOGICAL SCIENTIST

(*Continued from p. 452*)

forms and in the development of an information retrieval system.

If all this has not discouraged people from entering this field, they will find it very rewarding and seldom boring. It is a challenging field and full of surprises, but can be very enjoyable.

Conclusions

The biological scientist in an air pollution control agency is becoming of greater service as the larger districts are being formed which embrace agricultural areas. While it is not an altogether new role in history, it has often been neglected. His presence on the staff provides the air pollution control agency staff with a liaison to agriculture and public health, as well as an information source immediately at hand. His training in the life science fields not only allows him to help understand the biological problems, but also allows him to communicate these to the engineer.

In the Bay Area Air Pollution Control District, this position is filled by a biostatistician. Here the statistical duties are often not too sharply differentiated from the biological ones. However, these range from attempting to diagnose air pollution damage on orchids to the development of a mechanized punch-card information retrieval system. From this one can soon correctly surmise that monotony is not a problem.

Effluents' Analysis

(*Continued from p. 429*)

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MEMBERSHIP APPROVES NEW BY-LAW CHANGES

ARTICLE IV—MEMBERSHIP

Section 1. There shall be seven (7) classes of membership as follows:

(a) Individual Members: Any person of good character, interested in accomplishing the purposes of this Association, shall be eligible for Individual voting membership.

(b) Company Members (Local): Sole proprietorships, partnerships, firms, companies, corporations, and other business associations interested in accomplishing the purposes of this Association, whose manufacturing or production activities are within the boundaries of a single state shall be eligible as Company Members (Local). Company Membership (Local) shall entitle the holder to designate one (1) representative to voting membership. Such appointment shall be made in writing to the Association, and such representative shall be designated as a delegate.

(c) Company Members (National): Sole proprietorships, partnerships, firms, companies, corporations, and other business associations interested in accomplishing the purposes of this Association, whose manufacturing or production activities extend outside the boundaries of a single state, shall be eligible as Company Members (National). Company Membership (National) shall entitle the holder to designate one (1) representative to voting membership. Such appointment shall be made in writing to the Association, and such representative shall be designated as a delegate.

(d) Government Agency Members: Government agencies at all levels of government—federal, state, city, county, or district—interested in accomplishing the purposes of this Association, shall be eligible as Government Agency Members. Government Agency Membership shall entitle the holder to designate one (1) representative to voting membership. Such appointment shall be made in writing to the Association, and such representative shall be designated as a delegate.

(e) Organization Members: Organizations performing technical, scientific, research, education, consultant, or civic services including service clubs, interested in accomplishing the purposes of this Association shall be eligible as an Organization Member. Organization Membership shall entitle the holder to designate one (1) representative to voting membership. Such appointment shall be made in writing to the Association, and such representa-

(*Continued on p. 472*)

NEW HOOKER SYSTEM TO PROMOTE GOOD WILL

Hooker Chemical Corporation is taking a step in good neighborliness by improving its waste disposal practices in Niagara Falls, it was announced recently by Robert F. Schultz, production manager of the Eastern Chemical Division. A Hooker-developed system of unique design is planned to react and thus completely destroy at very high temperatures liquid organic residues instead of burying them in bulk or in used drums as in the past.

The reactor will eliminate the hazards of transporting these reactive, corrosive, and odorous substances from the plant to its dump site. This will permit discontinuance of dumping on company property along the riverfront behind the plant. That land is now slated to be cleaned up as a Hooker contribution to city beautification.

It is company policy to design all new plants and processes so as to avoid or eliminate air- and water-borne wastes and to reduce residues to the greatest extent feasible. Hooker's technical staff continually studies ways and means to diminish or eliminate wastes and installs anti-pollution devices.

IHF MARKS ANNIVERSARY

Industrial Hygiene Foundation observed its silver anniversary of progress in safeguarding industrial health, on the occasion of its 25th annual meeting at Mellon Institute, October 26 and 27.

Established at the Institute in 1935, the nonprofit foundation now has some 400 member organizations among companies and industrial associations throughout the nation. More than 500 officials of these groups gathered at the meeting to hear discussions by experts in industry, insurance, government, law, medicine, and science.

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LETTERS TO THE EDITOR

(*Continued from p. 421*)

volved and complicated and competitive that it should be approached by the air pollution control official (APCO) in a different manner than other operations. These points could have been made adequately in one short paragraph.

It is agreed that the chemical industry is highly competitive and to a large extent each operation has to be considered as a separate problem. Nevertheless, the first part of this section sets a negative tone for the whole report. No attempt is made to define any of the chemical industry's air pollution problems, even for well-known segments of the industry.

The last two paragraphs tell why the committee could not abide by the Technical Counsel's wishes in following the nine items that they required for these reports. The chemical industry may very well be one of several classes of operations which do not fit as well into the mold as some others, but the nine points are valid for most operations and should be held up as a goal to work toward.

Statement Challenged

The first statement in the section entitled "Program Outline" is one which is calculated to raise the "hackles" on many people in air pollution control. This is not because the statement is false, but because it places a narrow restriction on the relationship between the air pollution control official and the chemical plant. The statement is essentially that the air pollution control official's primary concern is whether or not a given plant is a nuisance in its particular location. This statement shows extreme lack of understanding of the excellent relationships that have been worked out between air pollution control officials, where they exist, and the industrial plants in most areas of the country. The mere existence of an air pollution control official with an area of jurisdiction implies that a community-wide air pollution problem has developed. If the air pollution control official's job is then to go around to each of the operations in his area of jurisdiction and establish whether or not each is a "legal" nuisance in its particular location, his program would probably never get off the ground. Instead of this approach, his job has to be that of deciding what kinds of air pollution are principally responsible for the community problems and then proceeding to develop regulations which will require all sources of troublesome air pollution to meet certain limits. These limits, of course, have to be based on knowledge of what all of the operations which are subject to the regulations can reasonably meet.

Oftentimes certain kinds of operations, in emitting highly irritating or toxic materials, must meet even tighter levels than those specified in the regulation. This is then the time for the APCO to come around to the plant to see whether or not it will be a nuisance in its location even after complying with the basic regulation. In this way control measures to meet both types of requirements can be installed simultaneously.

The list of questions which the control official can ask the chemical plant is a fair start on a questionnaire, but if a chemical plant operator and the air pollution control official are going to be helpful to each other much more detailed information on the nature of the plant's emissions must be developed.

The next section entitled "Comments on the Questions" is extremely general and contains information which most air pollution control people with any experience at all would already know.

In this section there is also a quotation from the *Air Pollution Handbook* on the health effects of air pollution, which has no place in this kind of a technical write-up.

At the very end of this report are found the only really positive statements in this report. Here I would make the suggestion that one of the functions of the APCA TI-2 Chemical Committee should be to supply data on equipment and methods which are currently used for air pollution control in some of the more well known chemical operations.

I think it would be a shame if an air pollution control association adopted this report in its present form as the best available information from the chemical industry.

BENJAMIN LINSKY,
Air Pollution Control Officer
San Francisco
Bay Area

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Arcadia, California

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San Francisco, California

King, Richard
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Oakland, California

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Riverside, California

Massoth, W. J.
Chicago, Illinois

Melser, L. Robert
Glendale, California

Morrow, Orville E.
Walnut Creek, California

(*Continued on p. 471*)

NEW BULLETIN OUT

"In a Fog About Electric Furnace Fume?" is the title of a new bulletin offered by Wheelabrator Corporation that discusses the three accepted hooding methods for controlling fume from electric arc melting furnaces—the furnace roof type, overhead canopy hooding, and direct shell evacuation.

Described in detail in this eight-page bulletin are the operating principles and advantages of each system to serve as a guide in evaluating each hooding method for a particular furnace fume control application. Illustrations of typical installations and diagrams are included to show the features and uses.

Write to Wheelabrator Corporation, 1322 S. Burkit St., Mishawaka, Indiana, for a copy of the bulletin "In a Fog About Electric Furnace Fume."

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Welcome New Members

(*Continued from p. 470*)

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Sarsfield, J. R.
Regina, Saskatchewan, Canada
Sherer, Robert J.
Albany, New York
Shoemaker, G. A.
Pittsburgh, Pennsylvania
Taylor, Frederick W.
Toronto, Ontario, Canada
von Bergen, John
Greenwich, Connecticut
Watanabe, Ichiro
Tokyo, Japan
Watkins, Wilbur O.
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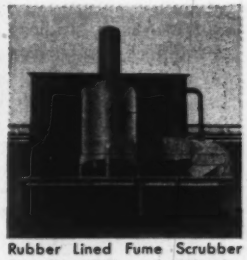

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Niagara Frontier Section

At the recent meeting of the Niagara Frontier Section, Al Rihm, Executive Secretary of the New York State Air Pollution Control Board, and his associates, Harry Hovey and Charles Maneri of the New York State Health Department and Samuel Moskowitz of the New York State Department of Labor were the honored guests.

The speaker for the evening was Jean J. Schueneman, Chief of Technical Services, Air Pollution Engineering Research Department of the United States Department of Health. This newly organized department is to be a part of the Bureau of Environmental Health. Congress, recognizing the need for a better environment, has ordered intensified efforts in this direction including consolidation of all such services.

Other Federal agencies now working on air pollution include the Bureau of Mines (SO_2 removal from flue gases, auto engine exhaust gas analysis, and catalytic and direct flame control of auto exhausts), the Bureau of Standards (photochemistry and atmospheric analysis methods), the Weather Bureau (dispersion and forecasting with emphasis on stagnation conditions), and the Library of Congress.

The work of the Department of Air Pollution comprises:

A Medical studies
- *1* Morbidity studies
- *2* Effects on body parts and functions
- *3* Animal studies in laboratory and regular air
- *4* Development of study methods
- *5* Mortality studies
- *6* Allergenic responses

B Engineering and physical science studies
- *1* Engineering Research and Development Group (auto fumes, dust collectors, incinerators, etc.)
- *2* Chemical Research and Development Group (detailed analyses, analytical methods, field test kits, and atmospheric reactions)
- *3* National Air Sampling Network (high volume sampling, carcinogens, precipitation and high removal of particulate matter and other materials from air to identify the constituents)
- *4* Instrumentation group (adaption of instruments to analysis, millipore tapes, smoke guides, dustfall collectors)
- *5* Agriculture group (effects on air pollution on plants and animals)

Mid-Atlantic States Section

The Mid-Atlantic States Section of the Air Pollution Control Association held its semi-annual technical conference November 17, 1960, at Consolidated Edison Auditorium, 4 Irving Place, New York City.

The meeting opened with brief welcoming addresses by Commissioner Arthur J. Benline of the New York City Department of Air Pollution Control and George T. Minasian, Director of Community Relations for Con Edison. "Air Pollution Education and Information" was the morning session theme. Training in the air pollution field was discussed by James P. Sheehy, Chief of Air Pollution Training at the U. S. Public Health Service's Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. Dr. G. Edward Pendray and Company public relations, Bronxville, N. Y., spoke on industrial public relations in air pollution, and Kenneth Kowald, Secretary to the New York City Air Pollution Control Department, presented a paper concerning information programs of official agencies. The role of public media in disseminating air pollution information was presented by Henry Walter of the *New York World-Telegram and Sun*.

The afternoon session theme was "What's New in Air Pollution?" Area planning and zoning for air pollution control was discussed by E. N. Bacon, Executive Director of the Philadelphia City Planning Commission. Adjunct Professor William T. Ingram of the Research Division, New York University's College of Engineering, spoke on engineering management of the air resource and Dr. Richard A. Prindle, Chief of the U. S. Public Health Service's Air Pollution Medical Program, presented recent activities and developments concerning medical effects of air pollution. The conference concluded with a presentation regarding air pollution of the future, by Dr. Raymond M. Manganelli of Rutgers University's Department of Sanitation.

West Coast Section

The West Coast Section's Second Technical meeting, held October 20 and 21, reflected the nation's increasing concern with auto exhaust pollution, as well as industrial air pollution. The well attended two-day session provided the auto problem with time equal to that devoted to industrial pollution.

Some 140 enthusiasts were on hand to hear keynoter and national Executive Secretary Arnold Arch pay tribute to the team effort fostered by APCA over the last 54 years.

(*Continued on p. 473*)

By-Law Changes Made

(*Continued from p. 468*)

tive shall be designated as a delegate.

(f) Sustaining Members: Individuals, companies, agencies, or organizations otherwise eligible for membership, interested in accomplishing the purposes of this Association, who wish to contribute a larger amount to aid its activities shall be eligible as Sustaining Members. Sustaining Membership shall entitle the holder to designate one (1) representative to voting membership. Such appointment shall be made in writing to the Association, and such representative shall be designated as a delegate.

(g) Honorary Members: Honorary Memberships, not exceeding two each year, may be conferred upon persons who have attained eminence in some field related to the control of air pollution or who have rendered valuable service to the Association. Honorary Members shall pay no dues. They shall have the privilege of the floor at the Association's meetings but may not vote. However, should any Honorary Member voluntarily choose to pay the dues of an individual member or should any Honorary Member be the designated representative of a company, government agency, organization, or sustaining member, he will have the voting privilege of the respective membership. Honorary Members shall be chosen as described in Article XVI, Section 2, of these By-Laws.

ARTICLE V—DUES

Section 1. Annual dues for membership in each grade shall be:

Individual Member	$ 15	
Company Member (Local)	50	
Company Member (National)	100	
Government Agency Member	50	(minimum)
Organization Member	100	
Sustaining Member	250	(minimum)
Honorary Member	None	

★ ★ ★ Section Hi-Lites ★ ★ ★

(*Continued from p. 472*)

Following the keynote address, Andrew C. Byrd, Chairman of the San Francisco Bay Area APCD Board of Directors, discussed air pollution from the standpoint of a layman, elected by the people and charged with the responsibility of an air pollution control program. Mr. Byrd emphasized that the success or failure of officials such as himself depends not only upon the sincerity of the official but to a large extent on the understanding and cooperation of private citizens and voters.

The afternoon session of the opening day was devoted to the control of air pollutants from motor vehicles. Dr. W. L. Faith, Managing Director of the Air Pollution Foundation, acted as Chairman. Dr. John T. Middleton outlined the program to be followed in controlling vehicular emissions in the State of California. Dr. Middleton is Chairman of the 13-man State Motor Vehicle Pollution Control Board which came into being as a result of action by the State Legislature earlier this year. Dr. Middleton stated that the Board is presently concerned with the hiring of a full time staff, the selection of one or more facilities for the testing of auto control devices, and the establishment of criteria for such control devices. He stated that they intend to set up their standards on a step-by-step basis. The state standards have already been established for CO and hydrocarbons. Yet to be determined are the minimum acceptable life span of devices, the minimum inspection standards, and the types of laboratories that will be required.

Charles E. Fisher, Project Administrator of the Norris-Thermador Corporation and Paul Magill, Consultant, each discussed the probable parameters that will be employed in designing auto exhaust control devices. Mr. Fisher explained that the Norris-Thermador Corporation has facilities to fabricate such automotive control devices as are anticipated. They are therefore encouraging inventors to submit their designs to them for tests with the desired purpose of mass producing these items in the near future. Following the presentation by the above three gentlemen, there was a panel discussion in which Dr. Faith, as well as John A. Maga, Chief, Bureau of Air Sanitation, California State Department of Health, participated. Panel topics included the responsibility for testing prototype devices, relative costs and efficiencies, and the probable initial dates of application.

The following day's discussion concerned industrial air pollution control. Clifton J. Seymour, Riverside County's Assistant Air Pollution Control Officer, acted as Chairman of the session, introducing speakers and moderating the panel discussion that followed.

H. Carter Austin, Research and Development Engineer of the Southern California Edison Company, discussed the control program pursued by his firm in the Los Angeles area. He noted the results of their studies into reduction of nitrogen oxides and visible emissions from power plant steam generators. He explained the two-stage combustion techniques which have materially reduced NO_x emissions to the atmosphere. The million-dollar precipitator at their El Segundo plant is, he noted, the first such application of precipitators to control particulates from oil fired power plants.

Kaiser Steel's Jack H. Smith, Director of Air Pollution Control Research presented his film covering the control of emissions from Fontana steel mill.

Details concerning the installation and operation of large carbon monoxide boilers were presented by Standard Oil of California's James W. Daily, who also serves as Program Committee Co-Chairman for the West Coast Section. These waste heat boilers are used to control carbon monoxide from refinery catalytic cracking units.

Bay Area Air Pollution Control Officer, Benjamin Linsky, in his paper, "Air Pollution Can Be Controlled," described the problems inherent to the San Francisco Bay Area and the effectiveness of legislation enacted to combat it. He stressed the Bay Area's recently promulgated Regulation 2, a comprehensive group of restrictions governing specific contaminants.

Robert L. Chass, Director of Engineering of the Los Angeles APCD, joined the aforementioned group in the panel discussion that followed. Particular interest was evidenced in the method of controlling visible power plant emissions, as well as noxious fumes from steel mill coke ovens.

New England Section

Dr. Albert E. Burke, former Director of Graduate Studies in Conservation at Yale University and presently a consultant in problems of industrial development, spoke at the Third Annual Cleaner Air Week Dinner Meeting of the New England Section. Dr. Burke's subject was "Conservation of Clean Air as a Natural Resource." Earlier in the day members and friends of the New England Section visited the power plant of the Hartford Electric Light Company and the Connecticut Light and Power Company.

E. J. HOUDRY COMPANY NEW MANUFACTURERS OF EXHAUST PURIFIERS

The formation of the E. J. Houdry Muffler Company to equip motor vehicles with catalytic exhaust purifying devices which are required by law in California is announced.

E. J. Houdry, chairman of the board of Oxy-Catalyst, Inc., and inventor of the catalytic process being used, made the announcement stating "all of the elements to make this process commercial have now been completely studied and tested."

Organization of the new firm caps a 14-months' crash program of engineering development to make the invention available at the lowest possible cost to the public.

G. P. Larson President

Gordon P. Larson is president of the new company, a wholly-owned subsidiary of Oxy-Catalyst, Inc., of Berwyn, Pennsylvania, of which he has been executive vice president and director for five years. "We are fully prepared," Mr. Larson said, "to serve the public in California as soon as the requirements of the Motor Vehicle Pollution Control Board are established." Once devices are approved by the board, it is understood that used cars being sold will require equipment before changes in registration can be made. Larson stated that the company's program covers the production and distribution facilities for serving this used car market.

Refinements Completed

Refinements based on 15 months and thousands of miles of road tests have been completed and incorporated into the design of the units for existing cars. Studies on plant facilities and the manner of distributing catalyst so as to reach the public at very low cost have been completed. Mr. Houdry and Mr. Larson both stated that they will present to the California board their complete program, as well as units for test, as soon as the board sets its conditions for receiving equipment from manufacturers. The device converts poisonous motor vehicle exhaust hydrocarbons and CO into CO_2 and water.

Specialists in the exhaust field, Oxy-Catalyst, Inc., has been manufacturing catalytic exhaust purifiers for ten years for small gasoline engines and expects to introduce a new muffler for diesel engines before the end of the year. Its air pollution control systems are successfully operating on many industrial plants in urban areas. All of the products which are sold for industry or vehicles contain various types of catalyst which have grown out of the work of E. J. Houdry.

Personalia

Philip T. Rogers has been appointed vice-president and general manager of the Arco-Wynn Valve Division of the Automotive Rubber Company of Detroit. Mr. Rogers was formerly the regional manager for the Hills-McCanna Company of Chicago.

* * *

George F. Collins has joined The Travelers Insurance Company in Hartford, Conn., as a Senior Research Associate in the Weather System Division. This section is part of the Environmental Meteorology Section which will be concerned with applied research in the field of micro-meteorology, including atmospheric diffusion and air pollution.

* * *

John von Bergen has been named Sales Director of the John Wood Company's Air Pollution Control Division. In this position Mr. von Bergen will coordinate sales activities of the firm. A member of the Board of Directors of APCA, Mr. von Bergen represented the President and Board of Directors of the Association at the world's first International Clean Air Conference in London.

Mr. von Bergen was formerly an engineering executive for General Electric Company and he leaves the post of Special Research Director for Airkem, Inc., to assume his new responsibilities.

* * *

Thomas A. Guerin, formerly a field sales engineer for Beckman Instruments, Inc., has been appointed Product Line Manager for electrochemical, hygrometer, amplifier, and leak detector product lines of the Scientific and Process Instruments Division.

* * *

William Butler, III, has been elected vice-president of Bell Intercontinental Corporation. Mr. Butler joined Wheelabrator Corporation, a Bell subsidiary, in 1959 as administrative assistant to the president and continued in a similar capacity with the parent company in July, 1960.

Research Appliance Company

Paul J. Zschau will be sales representative in Chile for their line of laboratory testing equipment and air and smoke samplers.

Kondoh Industries Ltd. has been appointed sales representative covering Japan, Okinawa, South Korea, Formosa, Hong Kong, India, and Philippines.

The Glass Developments Ltd., London, will be sales representative in England for their complete line of chemical pumps and air samplers. Glass Developments Ltd. is a firm manufacturing and selling products for the air pollution field and scientific industries in the United Kingdom.

Beckman Instruments, Inc.

Donald G. Drew is new Process Sales Engineer in the northwest section of the United States and western Canada.

Harry H. Bauer has been appointed Midwestern Regional Sales Manager for the Scientific and Process Instruments Division.

Robert L. Sinek, Herman L. Steudel, and **Frederick M. Teetzel** have been named Sales Engineers in the Midwestern Region.

James E. Tebay is the new Training Manager for the Scientific and Process Instruments Division.

Michael K. Lenihan, Harold J. Peper, Robert B. Sankey, and **Donn Thomson** have been appointed to the position of Sales Engineers in the Eastern Region.

Cincinnati Joins in Air Lift

PROJECT AIR LIFT—Cincinnati joined in APCA's Project Air Lift, a nationwide activity in which more than 50 North American cities participated this year. Shown above are J. Reed Hartman, vice-president, Cincinnati Gas and Electric Company and president of the Cincinnati Property Owners Association, assisted by Nancy Collins and Mary Ellen Giglio, reservation clerks for the American Airlines. The colorful attraction took place on Fountain Square in downtown Cincinnati.

DRACCO RECEIVES ORDER

An order for the first full-scale application of cloth bag filtration to open hearth steel furnace gas cleaning has been received by Dracco Division of Fuller Company. A ten-compartment Dracco Glass-Bag Filter will be used to clean combustion gases from a large oxygen-lanced open hearth furnace and prevent air pollution at a major steel plant.

The glass cloth baghouse will be equipped with sonic generators which will periodically dislodge accumulated dust and fume from filter bag surfaces. The patented apparatus removes dust deposits more effectively than methods previously employed and prolongs service life of the relatively fragile glass fabric. Sonic cleaning does not produce the damaging stresses in the cloth which occur when it is flexed or shaken.

The glass cloth collector will provide greater collection efficiency and is believed to cost substantially less than electrostatic precipitators which have been previously used for open hearth gas cleaning.

GERALD FISHER'S RECENT RETIREMENT MADE KNOWN BY MOBIL OIL COMPANY

The retirement of Gerald Fisher, pollution control co-ordinator, from Mobil Oil Company was announced September 21, 1960, by R. E. Lauterbach, the Company's general manager of manufacturing in Southern California. Mr. Fisher, who joined Mobil Oil Company 37 years ago, is widely known for his contributions to the oil industry's air pollution abatement program, having aided in the development and installation of many methods for the control of smoke, fumes, dust, and vapors resulting from refining operations.

For the past year Mr. Fisher has been on "loan" to the Western Oil and Gas Association, spending some 60% of his time as the association's air pollution control co-ordinator and as a member of the association's technical subcommittee.

In a letter of commendation to Mr. Fisher on his retirement H. G. Vesper, president of the association stated, "Your participation in the field of air pollution at the district, state and federal level has earned you a national reputation as a technical authority and this has been reflected by the respect shown to the oil industry in our relations with air pollution control authorities."

Mr. Fisher is a member of the Advisory Committee on Automobile Exhaust Standards for the California State Health Department and also a member of the technical task group on automobile exhaust research of the United States Department of Health, Education, and Welfare. He is chairman of the West Coast Section of the Air Pollution Control Association.

He is the author of several technical papers on air pollution. In 1959, he presented a paper at the Fifth World Petroleum Conference entitled "Air Pollution Prevention Through Engineering Design and Operation."

Representing Western Oil and Gas Association, Mr. Fisher testified on air pollution before the California State Legislative Assembly's Interim Committee on Public Health on September 28, 1955.

Mr. Fisher also delivered a statement, as a representative of the association, at the Conference on Air Pollution Research sponsored by the American Petroleum Institute and the United States Surgeon General's Office in New York, December, 1959. The paper dealt with the co-operative program on testing fuel composition.

A native of Scotsburg, Indiana, and a graduate of the University of Oklahoma, Mr. Fisher worked as a chemist in Colorado before joining the Mobil Oil Company in 1923 in a similar capacity. He became supervisor of laboratories in 1928 and chief chemist in 1930.

For three years during World War II he headed the Washington office of Socony Mobil Oil Company. Mr. Fisher returned to Mobil Oil Company in Los Angeles in 1943 and was appointed manager of lubricants and process products in 1944. In 1954 he was named pollution control co-ordinator.

He is a member of the American Petroleum Institute, Alpha Chi Sigma, a professional chemical fraternity, California Society of Professional Engineers, Pasadena Chapter, presently serving as chairman of its Air Pollution Control Committee. He holds membership in the American Ordnance Association, is a director of the All Nations Boys Club, the Petroleum Club of Los Angeles, and the Rotary Club of Vernon.

CLASSIFIED

APPLICATION ENGINEER—Growing manufacturer of dust control systems offers challenging opportunity in Cleveland home office to sales-minded engineer. Position involves application engineering, field surveys, proposal preparation and sales correspondence. Travel required. Several years experience in dust control or air handling preferred but not required. Our employees know of this ad. Interviews will be arranged for qualified applicants. Send complete resume and salary requirements to Box E, Air Pollution Control Association, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

INDUSTRIAL HYGIENE ENGINEER—Five years experience in field evaluation of dusts, fumes, gases, radiation, and noise exposures. Additional experience in stream and air pollution; also familiar with pilot plant development. Prefer Pittsburgh area. BSChE, Age 35. Salary open.

Help Boost APCA Membership

(*See page 426*)

AGREEMENT ANNOUNCED BY UNIVERSAL, ARVIN FOR TECHNICAL INFO

An agreement to exchange technical information and to co-operate in testing catalytic devices for purification of automotive exhaust gases was announced today by Universal Oil Products Company, Des Plaines, Illinois, and Arvin Industries, Inc., Columbus, Indiana.

Universal, a leading authority on catalysis, has developed both a catalyst and a catalytic muffler for reducing noxious exhaust emissions. Arvin, a major manufacturer and supplier of automotive parts, is actively engaged in development work in the same areas.

Law Stimulates Interest

Interest in automotive exhaust devices to reduce automotive exhaust emissions was stimulated by passage of a California law in April, 1960. In a joint announcement, E. H. Stonecipher, president of Arvin Industries, Inc., and M. P. Venema, president of Universal Oil Products Company, indicated that both companies have been independently conducting extensive research, development, and testing work in the field of automotive exhaust gas converter systems.

The co-operative effort is expected to accelerate certification, large-scale production, and commercialization of effective and economical exhaust control devices. The agreement will enable either Arvin or Universal to use the technical information of the other in marketing its catalytic device, and will enable Arvin, if it so desires, to market its device using catalyst purchased from Universal.

Arvin in Field Since '28

Arvin Industries, Inc., is one of the largest manufacturers of automotive exhaust systems for original equipment, having been in this field since 1928. It supplies parts for 19 of the 20 makes of passenger cars built in the United States and to seven of the 11 major truck producers.

Arvin has had an extensive research program with Battelle Memorial Institute over the past two years to develop the catalyst for reducing noxious exhaust missions, and will continue this program independent of the co-operative effort with Universal Oil Products Company.

Universal Oil Products Company is an important manufacturer and marketer of catalysts, and has been active in applying catalysis in the petroleum refining and chemical fields since 1935. Many of Universal's catalysts were specifically developed to control the chemical reactions of petroleum hydrocarbons.

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of the

AIR POLLUTION CONTROL ASSOCIATION

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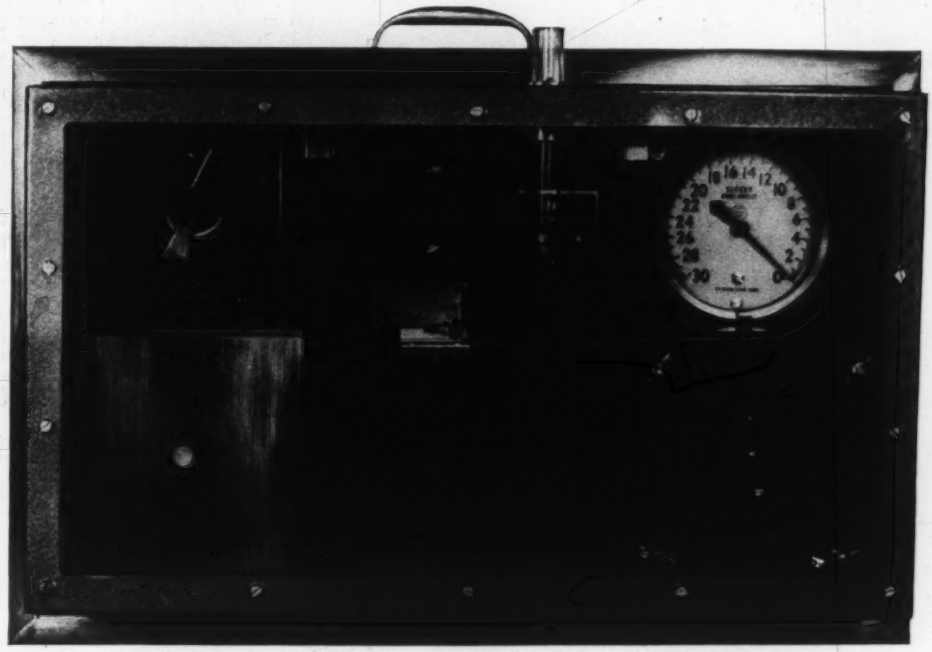

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*Patterned after sampler developed by the Robert A. Taft Sanitary Engineering Center, U.S. Public Health Service, Cincinnati, Ohio, and described in Nader, J.S.: "A Versatile, High Flowrate Tape Sampler," JAPCA, Vol. 9, No. 1, May 1959

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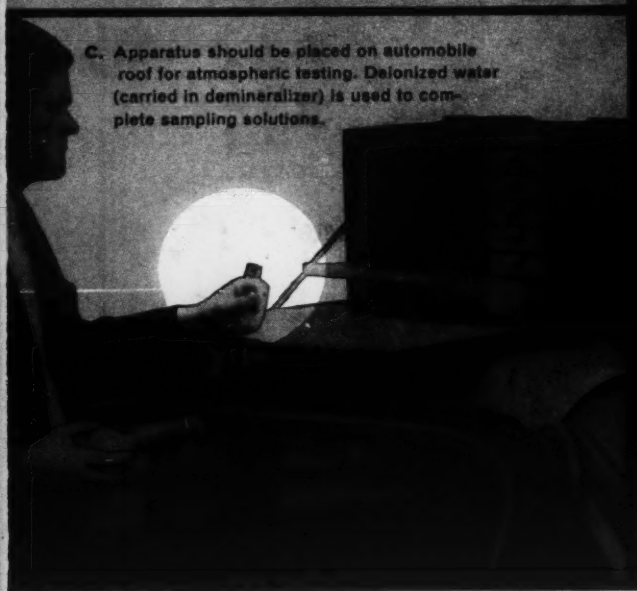
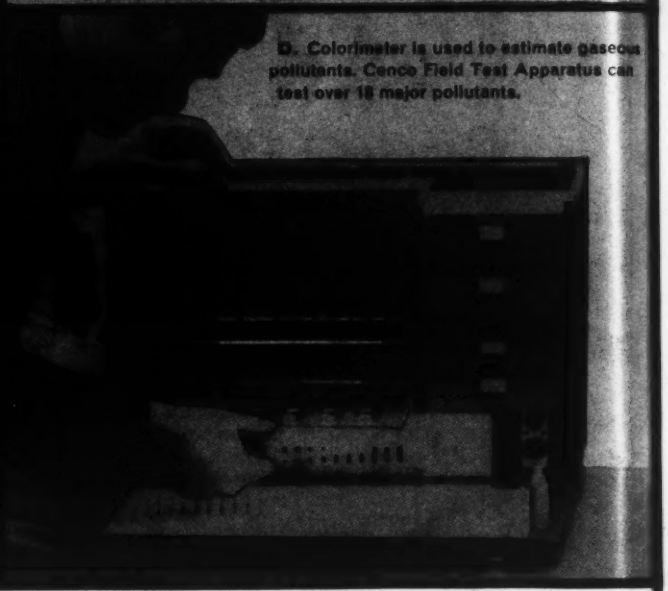


C. Apparatus should be placed on automobile roof for atmospheric testing. Deionized water (carried in demineralizer) is used to complete sampling solutions.



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